..The..

Mechanical Engineer.

VOL. XXXIII.

JANUARY TO JUNE, 1914.

THE SCIENTIFIC PUBLISHING COMPANY,
MANCHESTER.

THE
SCIENTIFIC
PUBLISHING CO.
MANCHESTER.

Supplement to the "MECHANICAL ENGINEER," July 3rd, 1914.

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The Mechanical Engineer.

An Illustrated Weekly Journal. Vol. 33, No. 832.

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Telephone No. 6655 City.

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21/-* " " Thick "
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Cheques and Postal Orders should be made payable to the Scientific Publishing Company, and forwarded to our Manchester Office, 53, New Bailey Street.

Advertisements, displayed, for insertion in current issue should reach our Manchester office not later than first post Tuesday morning, and small prepaid advertisements not later than first post Wednesday morning.

The Lubrication of Cutting Tools.

In the course of the discussion on Prof. Ripper's recent paper on lathe cutting tools, exception was taken by some of the speakers to the fact that in his experiments the cutting tools were not lubricated, and that this was not in accordance with practice. We pointed out at the time the desirability in conducting tests of keeping the number of variables as few as possible, and that on this score he was fully justified in his procedure. It seems also desirable to point out in view of some of the observations made to point out that practice in respect to the lubrication of cutting tools varies considerably, even in the same workshop. Some men will use a lubricant, others won't, while others again pursue a course which suggests a great deal of ignorance as to the primary object of tool lubrication. Before the advent of modern high-speed cutting steel, lubrication, when adopted, was generally limited to the small amount permissible with a can placed over the lathe centre and from which the supply dripping on to the lathe tool was regulated by a small cock. Such lubrication was invariably confined to wrought iron or steel, and different foremen had different recipes for the composition of lubricants to which a certain amount of mystery and virtue was attached, and for which little scientific explanation was offered. If a workman were asked why he used no lubricant when cutting cast iron, brass, or white metal, he would probably reply he had never seen any and therefore it wasn't necessary, while others would perhaps assert that it would interfere with the action of the cutting tool. If he had been brought up to use oil with a certain material and some special mixture with another he would continue to do so as a result of habit rather than of experience. We have so far passed beyond this stage that it is hardly necessary to explain that the object of lubrication in the first instance is to prevent the point of the tool from overheating and so losing its temper and necessitating renewal, though the secondary object of preventing distortion of the work

from the same cause is sometimes of importance, while the actual lubrication of the cutting edge is also not to be overlooked. The overheating that occurs when metal is being cut is, of course, the direct conversion of the work of the machine into heat caused by the continuous shearing of the metal. In the case of materials that possess little tenacity and ductility, and in which, as a consequence, the shavings break off in chips as with cast iron, brass, &c., the heat is not conveyed by contact to the piece in the lathe as it is in the case of wrought iron and steel where the turning is more or less continuous. This question of lubrication has already been the subject of experiment, and though the absence of a lubricant with cutting tools of high-speed steel does not appear to be so detrimental as with tools of ordinary carbon steel, Mr. Dempster Smith (*vide* paper Manchester Association of Engineers) found that lubrication even with high-speed steel increased the *durability* of the tool about 25 per cent. or conversely gave the same length of life with a 12 per cent. higher speed. The results depend to some extent on the nature of the lubricant, and as we have stated recipes vary in different shops and for different classes of work. Oil, soda, and water, as main constituents have, however, obvious justifications for their use. For carrying away heat water with its high specific heat is unrivalled apart from its merit of cheapness, soda is useful in preventing the work rusting as it would be liable to do if water were used alone, while oil serves to lubricate the cutting edge and possibly also by some obscure chemical action to preserve its temper. There are many points, however, in connection with the subject which still remain unexplained. Why, for instance, should paraffin be a better lubricant when cutting aluminium—as it is reputed to be—than oil, and why should turpentine be better than either when drilling glass? Careful thought suggests several possible explanations, but we do not put them forward, for without actual knowledge of the facts, and that at present is not available so far as we know, they would bear the appearance of guesses at conundrums. The first point to determine is whether and to what extent the statements implied in these and other similar questions relating to tool lubrication, are themselves true, and the fact that no immediate answer is available shows the wide field open to enquiry.

Welds in Boilers.

Although welds are extensively used in boiler construction—as, for instance, in the longitudinal seams of furnace tubes of Lancashire boilers and the firebox crowns of small vertical boilers—and, as usually situated, are not objectionable owing to the fact that the pressure in the boiler tends to keep the welds in compression, it should be clearly recognised that when welds are subjected to tension they may be a source of danger, and for that reason should be avoided as far as possible. An illustration of this is afforded by some particulars given in the last issue of "Vulcan" respecting a disastrous boiler explosion that occurred a few months ago at Mährens, in Germany. The boiler was of the water-tube type, resembling the Babcock in general outline, but differing materially from it in the construction of the water spaces, which, instead of being in staggered elements for each vertical row, were formed of two large rectangular boxes uniting the front and back ends of all the tubes. The bottom of these boxes, instead of being riveted in, had been bent over and welded. Such a weld obviously could not be well made, as from its position it could not be supported on an anvil during the process of welding. The weld, in fact, must have been what is known as a "dab-weld," the objectionable feature of which is that when completed it is impossible to be certain on inspection whether it is sound or not, and in this case it was impossible to inspect it on the inner side, as it was inaccessible, and, as events proved, it must have been very defective, for it gave way after it had been at work about nine months, with the result that the flat bottom of the front water-box was blown right out. The escaping water and steam, at a pressure of 120lbs. on the inch, projected the boiler violently from its seat, and, after turning a series of somersaults, it landed in the bed of a stream some considerable distance away. Enormous damage was done, the factory in which the boiler was located being completely wrecked, while two men were killed. It may be argued that the application of the hydraulic test in the first instance would have revealed the defect, but in Germany this is insisted upon by Government regulations, and the fact that it did not avert the explosion shows how unreliable such a test may sometimes be. Indeed, it is one of the cases in which the hydraulic test may do more harm than good by developing an incipient fracture or defective union of the weld and making its progress under working conditions subsequently more rapid. The danger of welds of this kind is pretty well recognised by boilermakers in this country, though we can recall many failures in past years when the shell seams of small vertical boilers were often made in this way and put upon the market by makers with the proud announcement that the boiler was seamless. Welded tubes have been employed in water tubes, but even these, though of small diameter, are now avoided for modern high pressures, owing to the number of failures that occurred. It is customary, of course, still to use welded smoke tubes very largely, but these are in another category, since the pressure acts externally and thus tends to close the weld instead of to rip it open.

NATIONAL ILLUMINATION COMMITTEE.

A provisional committee, formed of representatives of the Illuminating Engineering Society, the Institution of Electrical Engineers, the Institution of Gas Engineers, and the National Physical Laboratory, held a meeting on November 29th last, at which arrangements were made for the formation of a National Illumination Committee, to be constituted according to the statutes of the International Illumination Commission, with the primary object of affiliating Great Britain to that Commission. The provisional committee recommended that the National Committee should consist of five representatives of each of the three technical societies and two representatives of the National Physical Laboratory. This recommendation has been adopted, and the following have been nominated as members of the committee: By the Illuminating Engineering Society—Mr. Leon Gaster, Mr. F. W. Goodenough, Prof. Silvanus P. Thompson, and Mr. A. P. Trotter (this society has not yet nominated its fifth representative); by the Institution of Electrical Engineers—Mr. F. Bailey, Mr. W. Duddell, Mr. K. Edgcumbe, Mr. Haydn Harrison, and Prof. J. T. Morris; by the Institution of Gas Engineers—Mr. E. Allen, Mr. J. Bond, Mr. W. J. A. Butterfield, Dr. H. G. Colman, and Mr. H. Watson; and by the National Physical Laboratory—Dr. R. T. Glazebrook and Mr. C. C. Paterson. The first meeting of this National Committee recently took place, when the following were chosen as officers: Chairman, Mr. E. Allen, of Liverpool; vice-chairmen, Mr. W. Duddell and Mr. A. P. Trotter, both of London; and hon. secretary and treasurer, Mr. W. J. A. Butterfield, of London. Great Britain is entitled to two delegates on the Executive Committee of the International Illumination Commission, and Dr. H. G. Colman and Mr. W. Duddell were accordingly appointed by the committee as the delegates from this country.

STATUS OF THE LARGE GAS ENGINE IN EUROPE.*

BY PROF. PAUL LANGER.

About 11 years ago the large gas engine was brought to a high state of perfection by the Maschinenfabrik Nuernberg in the form of the double-acting four-cycle type, with two cylinders arranged in tandem. It was recognised that the principles on which to base the design of large gas engines should involve (*a*) the greatest possible accessibility of all parts exposed to the gases of combustion, and (*b*) relieving the cylinder wall of the weight of the piston.

In the case of the steam engine a leaky piston does no further damage than to increase the steam consumption. The governor automatically adjusts for a longer cut-off and the engine pulls through as long as the boiler furnishes sufficient steam. With the gas engine, a leaky piston causes ignition at the wrong time, which means a release of heat energy at a time and place when this energy can do no useful work. The attention needed to prevent such disturbances cannot be given when access to such vital parts as pistons, stuffing-box packings, and valves can be had only after a long and difficult job of disassembling. The author knows of an engine which, after six years of continuous day and night operation, showed only 0·015in. wear in the diameter of the cylinder. This success, although immediately traceable to the careful attention this machine received, is nevertheless indirectly due to the designer, who made it possible to give such attention through the excellence of his design.

The attempt to attain stratification of the mixture inside of the cylinder has led to very complicated valve gears. It was hoped that a gas valve, which remained open during only a part of the surface stroke, would direct the gas in such a manner that a combustible mixture would be present at the point of ignition even under the lightest loads, while the balance of the combustion space would be filled with inert air. The result, however, did not justify this hope. Instead of stratification there was only a bad mixture, resulting in irregular and uneven operation. To-day the hope of attaining stratification can be considered as being finally disposed of, and designers have returned to the simple throttling valve gear.

Throttling of gas and air simultaneously, or, in other words, regulation of the quantity of mixture only, is to be preferred to the throttling of gas only, as the former method is less sensitive and makes possible a more certain control of the power developed by the governor. The result of throttling is to reduce the quantity of mixture drawn into the cylinder during each stroke, on account of the reduced openings for gas and air. The volume of the charge remains the same, as the cylinder is always completely filled. The density of the charge will become less and correspondingly its weight and the amount of energy supplied.

The connection between the governor sleeve and the throttling mechanism should be changed so that in the low positions of the governor the throttling action is more intensive than in the upper positions. This action can be accomplished in a simple manner by off-setting the connecting link between the governor and the throttling valve, similar to the arrangement found in Corliss valve gears. This allows a uniform utilisation of the total lift of the governor, and consequently stable and quiet regulation, without any complication whatever.

Even the best considered scheme of regulation will not avail if the proportion of mixture, that is, the ratio of gas drawn in to air drawn in, is not properly controlled. In engines that have separate pumps for air and gas, as usual in two-cycle machines, where, therefore, air and gas are furnished in measured quantities, it is a comparatively easy matter to get the proper proportion, at least, at full load. Difficulties are found, however, in four-cycle machines, where gas and air are drawn in by the working piston in parallel. In this case the proportion of mixture is not readily controlled, because the quantities drawn in depend not only on the free opening of the admission valve, but on the product of this opening area and the velocity of flow through it. Incidental changes in pressure, due to static or dynamic causes, may influence this velocity strongly. The difference in specific gravity must be considered when deciding upon the proportions of the ports for correct mixture in engines that use gases lighter than air. A disregard of this fact leads to too rich mixtures and the engine becomes choked with gas. The many failures of engines working with coke oven gas are partly explained by wrongly proportioned gas ports. At least, proper operation resulted in many cases from materially reduced gas ports. To avoid too intensive a throttling action and consequent reduction of power, the piping and other passages leading to the mixing valve must be proportioned liberally, so that the total drop in pressure is advantageously concentrated within the valve itself.

For a long time great difficulties were presented by the problem of driving variable-speed blowing engines by four-cycle gas engines. In most cases the gas arrives at the mixing valve under a pressure of several inches of water above the atmosphere, while the pressure of the air is somewhat less than atmospheric. When the machine is run slower the suction action of the piston is reduced and the intake velocity of the air decreases more rapidly than that of the gas, until finally it is reduced to such an extent that nothing but gas enters the cylinder. It is self-evident that, even before this point is reached, the engine will choke with gas and will stop. A governor which regulates the quality of the mixture would only favour this suffocation of the engine with gas. In such cases, too, the conditions are improved by intensive throttling at normal speed.

Improvements of design as well as improvements in foundry practice have reduced the breakage of cylinders to a point where it is now rather a rare occurrence. Views upon the most suitable shape still differ, however, considerably. While in all other details of large gas engines standard designs have been developed, which serve all purposes, the cylinder designs still vary considerably. The fact that some designers, after careful experiments, have abandoned the split jacket cylinder in favour of the normal one-piece cylinder, while others, also after careful experiments, have gone in exactly the opposite direction, and split not only the jacket but also the inside cylinder, seems to show an uncertainty in judging the causes of breakage. These differences in design, however, are caused largely by fixed ideas of the purchasers, whose special wishes are complied with by clever salesmen. The one-piece cylinder is just as strong as the split one. The split cylinder has come principally from the desire to avoid initial stresses in the direction of its axis, which put the inner cylinder under tension on account of the fact that in casting it cools later than the rest of the casting. Besides, by casting the two halves separately it was attempted to obtain as dense as possible a wall for the combustion chamber. Finally, splitting the cylinder has the advantage that customers who consider a cylinder liner the proper construction can be satisfied, inasmuch as the insertion of liners in one-piece cylinders presents some difficulties, though these are not to be considered insurmountable.

Besides the advantage of simplicity and the absence of the danger of leakage in the highly-strained cylinder joint, the one-piece cylinder allows a better transmission of the forces from the cylinder to the frame. As a matter of fact, breakage on account of strains in the casting or from expansion due to heat has not occurred in cylinders that were properly reinforced. Improvements in foundry practice have undoubtedly helped to avoid such breakage.

While breaks have an origin in the strains set up by irregular cooling of the casting or by irregular heating in operation, cracks of an entirely different nature have been observed on the walls of the combustion chamber. These so-called fire cracks always start in a place where the transmission of heat to the cooling water was impeded from some cause or other. The cause of these cracks is to be found in the stresses produced by unequal temperatures within the same wall. In the smooth and homogeneous wall the differences in temperature of the different strata are small and the temperature of the wall is comparatively low, as long as accumulated scale or similar causes do not offer an obstacle to the transmission of heat. When, however, the capacity of the wall for conducting heat, or the rate of transmitting heat to the cooling water is reduced, there will be accumulation of heat which will cause a considerable rise of temperature

* Abstract of paper read before the American Society of Mechanical Engineers, New York, December 4th, 1913.

during the expansion and exhaust strokes. The material will tend to expand according to the average temperature of the wall, and it will be able to do this without resistance because it was under tension on account of the strain in the casting. In operation, therefore, the strain will be relieved. On account of temperature differences, however, in different strata of the wall, there will be stresses in the wall itself, compression in the hotter zones and tension in the cooler ones.

This condition of stress can be compared with that existing in a bar being bent towards the inside of the cylinder. In the hotter layer the expansion, being resisted, causes compression stresses, and in the colder layers there will be tension stresses. As soon as cold mixture is admitted during the next suction stroke the surface of the wall is cooled intensively. The inside layers of the wall cannot follow rapidly enough to cause the establishment of settled conditions corresponding to this flow of heat. The mean temperature of the wall, and consequently its average expansion, can only be affected very slightly during the first moment of internal cooling by the entering cold mixture. The innermost layer will be under strong tension on account of the sudden cooling. This jumping of the temperature acts upon the material in much the same manner as sudden flexure from the inside to the outside would. The inside layer of the wall of the combustion chamber, therefore, is exposed to the same kind of stresses as the outside fibre of a bar that is continuously bent in both directions by blows. The stresses which occur under these conditions are about proportional to the difference in temperature, the coefficient of heat expansion, and the modulus of elasticity, if, indeed, one can speak of such in the case of cast iron.

This is an extraordinarily unfavourable case of strain. Cases of strain on account of sudden changes of temperature are not rare, but these conditions are worst in the cylinders of gas engines, on account of the rapid succession of the changes in temperature. A mathematical deduction of these stresses is out of the question on account of the impossibility of obtaining even half-way accurate data on the distribution of temperature at any one moment over the different zones of the wall. If we bear in mind, however, that a difference in temperature of 200° Fah., when the expansion is restrained, corresponds to a strain of about 15,000lbs. per square inch, we are surprised to find that cracks do not occur more often. The occurrence of a crack, which in the beginning is scarcely $\frac{1}{8}$in. deep, apparently relieves the strain to a certain extent, and only the natural tendency of the cast material to continue to break, together with the external mechanical forces, causes the crack to open further. In most cases drilling and caulking at the end of the crack will stop this. The timely discovery of the crack is, however, rather difficult, as it is not open after the wall is uniformly cooled.

The first step in combating the occurrence of these cracks must reduce their real source, *i.e.*, the differences in temperature, to an amount that is harmless. As the sudden changes of temperature are caused by the very nature of the gas engine cycle, these attempts must be confined to avoiding all irregular ignition and slow combustion, both of which are likely to increase the temperature of the cycle beyond the normal, as well as the difference in temperature when the sudden change occurs at the beginning of the suction stroke. Furthermore, it is necessary to make the conductivity of the wall uniform in order to avoid all accumulations of heat in the material. It is therefore necessary to avoid all accumulations of material. The commonly used globe or onion shaped passages for inlet and exhaust valves are therefore not suitable, and lately the form shown in Fig. 2 is very properly preferred. Here the valves are brought close to the inner surface of the cylinder.

In a much more effective manner than by measures of design can the heat cracks, and, in fact, all cracks that occur in gas engine cylinders, be avoided by proper choice of a material, the constant of which (coefficient of heat expansion multiplied by modulus of elasticity) is less with the same tensile strength than in the case of the cast iron. The less the expansion from heat (which is the real cause of the strain) and the more elastic the material, the less the strain. Considering the enormous progress which metallurgical science has recorded in the past few years, a solution of this question of material should appear possible, and the more so as nickel steel alloys have actually been made for accurate rules, in which expansion from heat cannot be detected at all.

An investigation of the constants in question (coefficient of heat expansion multiplied by modulus of elasticity), upon which depends, according to the foregoing, the strain of the material resulting from uneven temperature, shows that steel castings are not suitable for gas engine cylinders. The larger expansion due to heat, as compared with cast iron, and the very much higher modulus of elasticity, causes increased stresses, while the strength of steel cast is not proportionately greater. Experience confirms this conclusion.

The principal task upon which the gas engineer is labouring incessantly, besides that of enhancing the reliability of the machine, is that of making it cheaper, partly by simplifying its construction, partly by increasing its output. At present it can hardly be imagined that the gas engine can be made cheaper by making its construction simpler, now that the complicated valve gears have disappeared. Reduction of weight is not to be recommended. Until recently experience has demanded a continuous increase of engine weights. Economy in material would reduce reliability and length of life of the machine. The mechanism has been developed into standard designs, so that in this detail there is nothing to be saved. Somewhat better prospects seem to be opened by the attempt to reduce the cost by increasing the output of the machine of a given size.

Increasing the number of revolutions per minute is not practicable—at least, not with less combustible gases, such as blastfurnace gases. The reliability of the machines would be lessened, not even considering the fact that the time available for the combustion of the mixture is too short and that therefore the losses on account of incomplete combustion would become too large. A comparison of the results of operation of gas-operated blowing engines, which run relatively slow, and engines driving dynamos, proves that the former require considerably less repairs than the latter. Increasing the number of revolutions would increase the idle time on account of repairs, and a gain in output can hardly be expected.

A method for increasing the output which lately has attracted renewed interest consists in increasing the pressure of the charge and simultaneous scavenging of the exhaust gases. In this manner a given suction volume of an engine can accommodate a larger weight of charge, and greater output of power can be attained. The original purpose of this method, which has been known in England for many years, was the avoidance of pre-ignition by scavenging the cylinder of what remained of the hot exhaust gases. It is the competition into which the gas engine has lately had to enter

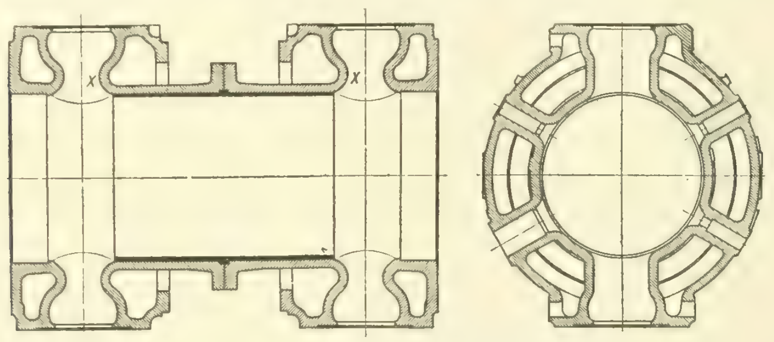


FIG. 1.—SPLIT JACKET GAS-ENGINE CYLINDER, WITH SPLIT INSIDE CYLINDER. POINTS AS AT X ARE SUBJECT TO HEAT ACCUMULATIONS AND THEREFORE TO CRACKS.

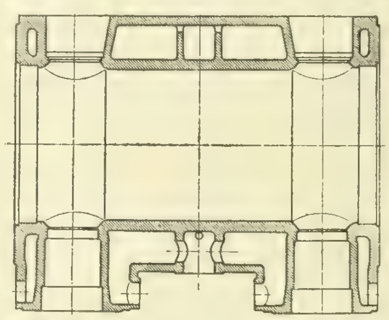


FIG. 2.—RECENT DESIGN OF ONE-PIECE GAS-ENGINE CYLINDER, WITHOUT GLOBE-SHAPED PASSAGES TO VALVES.

with the steam turbine that has brought to the front the possibility of increased power output, and consequently lower cost of the machine per unit of power.

The simplest method of realising the scheme of scavenging and charging consists in closing the exhaust valve late and opening the inlet valve early. The time during which both valves are open is used for scavenging. In order surely to avoid loss of gas, the charging with gas is only commenced after the exhaust valve is closed. At the end of the suction stroke the mixing chamber must be cleansed of combustible mixture by scavenging, or rinsing, with pure air, as otherwise backfires would occur at the beginning of the next scavenging period. Gas and air are brought to the machine under a pressure of about 3lbs. per square inch gauge. On account of this increased pressure the weight of the charge is about 20 per cent. greater than that of the normal method. Scavenging the combustion chamber also furnishes further space for fresh mixture. Experiments have shown a mean effective pressure of about 100lbs. per square inch. In continuous operation, in so far as we can speak of such in experiments, mean effective pressures of 85lbs. per square inch can be reached.

Undoubtedly such results present much that is attractive, especially as the output can still be increased by further increasing the pressure, and as this would give to the gas engine the capacity for overloads which heretofore it did not possess in the same sense in which steam engines do. Experiments have also proved that these overloads can be had without an increase of the maximum pressure. This is done by reducing the compression.

In spite of the lower compression the heat consumption per unit of power was not increased. It seems that this result is explained first by better combustion of the charge, which is not contaminated by the remains of the exhaust gases, and secondly by a decreased percentage of loss in the cooling water. The predominating influence can only be found by means of carefully measured heat balances, which at present are not available. The increased temperature of the cylinder walls, which has been found thermo-electrically, has caused objections against continued operation with scavenging and forced charge. A certain justification cannot be denied to these objections. The decrease of continuous loads is the very factor that has contributed to overcome the difficulties of operation. To endanger a regular operation by increasing the power output must appear to be a dangerous experiment in just such cases where the equipment is insufficient and an increase is highly desirable. The disposition on the part of operating engineers to await developments is easy to understand. The present satisfactory operation, which is the result of years of toil, is making these engineers justly conservative.

The endless desire of gas engine builders to improve the economy of the gas engine has lately brought to the front interest in the utilisation of waste heat. According to experience, a blastfurnace gas engine dynamo consumes in continuous service on the average about 16,000 B.T.U. per kilowatt-hour. Of this amount of heat only 3,412 B.T.U. is converted into electrical energy. Of the balance, 12,588 B.T.U., the mechanical, electrical, and radiation losses have to be regarded as unredeemable, as well as the energy contained in the unburned gases. The heat in the cooling water, about 4,800 B.T.U., and that in the exhaust, about 5,200 B.T.U. per kilowatt-hour is, however, available for a more or less perfect further utilisation. The high temperature of the exhaust, about 880° Fah., measured at the exhaust flange, makes possible its immediate use for the generation of steam in boilers, which have to be placed as closely as possible to the exhaust chamber. As a matter of fact, it is possible to obtain about 2lbs. of high-pressure steam per kilowatt-hour of the gas engine.

The utilisation of the heat in the cooling water is not possible as directly as this. The further use of this heat for power purposes means the generation of steam, and this requires a considerably higher temperature than that customary to-day in large gas engines. Karl Semmler suggested as long ago as 10 years that gas engine cylinders be cooled with water hotter than 212° Fah., and that this water be put under pressure in order to avoid the generation of steam in the jacket. Evaporation commences only outside of the jacket when the superheated water is conducted through a throttle valve into a steam drum. It may be easily understood that this "hot cooling" scheme has been regarded rather sceptically for a long time. About a year ago it was decided at the Rombacher Huetten Werke to try Semmler's cooling method on an 800 kw. tandem engine. The results in operation, which are available to-day, are entirely favourable. The hot jacket not only did not hurt the cylinder, but it caused apparently a softer and quieter operation of the machine.

The use of distilled water in a closed cycle, the considerably higher temperature of the outer cylinder wall, which causes nearly equal average temperatures of the inner and outer cylinder walls, are surely advantages which, if the favourable experiences last, merit more consideration than the recovery of waste heat. The amount produced is, in the case of the engine mentioned, about 1·1lbs. of steam of low pressure per kilowatt-hour. There is no doubt that this figure can be very much improved by designing the cylinders more suitably for this purpose, by careful insulation, and by connecting the cooling water from the piston, which heretofore has not been used.

The results achieved in recovery of waste heat will be of different practical value for different types of blastfurnace plants. Where there is a steam plant in addition to gas plants, it would be advantageous to shut down some of the boilers and substitute steam from the waste-heat boilers by connecting them to the steam mains, because this steam can be produced almost without cost for attendance and for fuel, and therefore as cheaply as is possible.

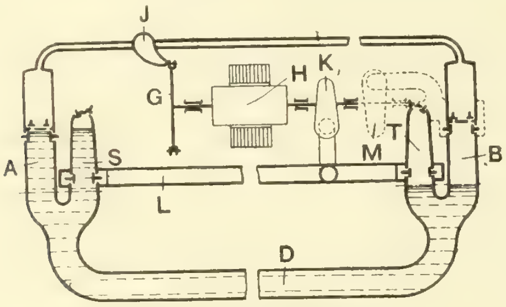
In conclusion, it is well to touch, in a few words, upon the competition between the gas engine and the steam turbine, which lately has become very keen. The steam turbine has doubtless made much progress during the last few years. In its perfected form, in which we know it to-day, it is a thoroughly reliable machine. Its overload capacity, with nearly constant steam consumption per power unit, is limited by its accessories, as boiler and condenser. In addition, there is its principal advantage of lower first cost as compared with the gas engine. Its disadvantage is the higher consumption of heat per unit of power. The gas engine produces approximately twice the amount of energy from a given amount of heat, and is therefore vastly superior as a fuel saver from the economic point of view. To the business man, however, the question of lower first cost often appeals more strongly. The favourable balance-sheet of the current year pleases him better than the quiet satisfaction of the knowledge that he has saved valuable treasures of fuel for his great-grand-children. But even from this standpoint the gas engine can be victorious over the steam turbine in cases where the available waste gases are not so abundant that their combustion under steam boilers would suffice to satisfy the existing requirements for electrical energy. Whether and to what extent these conditions will be changed by the new method of surface combustion is a matter which the future will show.

BROWN, BOVERI GAS TURBINE.

THE accompanying diagrammatic sectional view shows a combination of gas motor and compressing means, comprising explosion chambers disposed at each end of a liquid play pipe, the invention of Messrs. Brown, Boveri, & Cie., of Baden, Switzerland. The apparatus is shown in combination with a gas turbine G, which, for instance, drives an electric current generator H, the combustion chamber J of the turbine being supplied with the necessary fuel by the chambers A and B, respectively. On the turbine shaft there is also mounted a blower K communicating with the conduit L, which serves for scavenging the combustion chambers S, T. In operation, when a combustion takes place in the chamber S, the chamber in that case being completely or approximately completely filled with water, the column of water D is accelerated under the influence of the expanding gases. Through the kinetic energy of the column, there is compressed on the one hand a gaseous medium in the compression chamber B which is then expelled and forced into the combustion chamber J, and on the other hand simultaneously or approximately simultaneously a gaseous medium is compressed in

the chamber T, which gaseous medium is to be used for the next combustion in the compressor. As soon as the pressure of the gases in the chamber S, in which the combustion took place, has sunk during their expansion below the outside air pressure (which is due to the column of water which continues its surging movement even after the cessation of the gas pressure), a gaseous medium, for instance, fresh air is drawn into the chamber A as well as air and fuel mixture, respectively, into the chamber S after the residues of combustion have been expelled from this chamber by injected scavenging air, while the exhaust valves are open and the admission valves closed. A combustion is then effected in the chamber T, and thereafter the same process is repeated in a reverse direction. Each stroke therefore is a working or effective stroke. In the combustion chambers S, T therefore combustions are always taking place, and main compressions (so called as to distinguish them from the compression of the media required for the compressor itself) in the compression chambers A, B. In consequence of this separation at each end a practically isothermal main compression is obtained. The two processes, *i.e.*, combustion and main compression, do not mutually deteriorate the efficiency. The material is preserved, and the air which is to be compressed and to be used outside the apparatus is not mixed with the residues of combustion.

The compression of the air, gas, or of the gas and air mixture both for the chambers A, B and S, T may be effected in stages. As an example the preliminary compression may be effected by means of the compressor M shown in dotted



BROWN, BOVERI GAS TURBINE.

lines, the final compression taking place in the chambers A, B and S, T. Graduated compression may also be obtained by suitably arranging several compressors, for instance, the compressor K and M in series. Further, the compression may be sub-divided by arranging the chambers A and B in series and by pre-compressing the air in A and further compressing the same in B. Also, for instance, air may be compressed in the chamber A and gas in the chamber B in order to produce a combustible mixture subsequently where desired, for instance, in the combustion chamber J of the turbine. Pistons may if desired be interposed in known manner between the gases which are used for combustion and the column of water in order to reduce transmission of heat from the expanding hot gases to the water and to prevent evaporation of water and mixing of the resulting steam with the gases in the combustion chambers. The compression of air, gas, or mixture necessary for the combustion required for accelerating the water column may be effected partly or wholly in a chamber separated by a valve from the chambers S, T, respectively, to which separate chamber air may be supplied from another source or from a device driven by the gas turbine, or by the compression chambers A and B, respectively. The exhaust gases of the turbine are preferably used for pre-heating the compressed air required for combustion.

In the arrangement described the column of liquid is always accelerated under the influence of an expansion of gases caused by the action of an explosion, whereby the medium to be compressed and to be used outside the compressor is delivered in the required state of compression to the combustion chamber of the gas turbine, while approximately at the same time the air required by the compressor itself for combustion or the mixture for the next following combustion is compressed, and fresh air or gas, or a gas and air mixture, is sucked in at the opposite end of the column of liquid (that is, at the end where the explosion has just taken place), whereupon the cycle of operations is repeated in the opposite direction.

ROLLER AND BALL BEARINGS.

IN a lecture recently delivered before the Institution of Automobile Engineers, Prof. John Goodman, of the Leeds University, dealt in an interesting manner with the design of ball and roller bearings. The lecturer has given the subject considerable attention during the past 15 years, during which time he has conducted many experiments on both types of bearings. One result of his investigations has led to the establishment of the following formula which gives the maximum working load in pounds to be allowed for any given ball-bearing.

$$\frac{K\,m\,d^2}{N\,D + C\,d};$$

where m = the number of balls in the bearing;
d the diameter of the balls in inches;
N = revolutions per minute;
D = diameter of ball race, diameter being taken from the point of contact of the ball with the race, or for a thrust bearing D = the diameter taken from the centres of the balls. The constants C and K are as follows:—

For thrust bearings:—

	C.		K.	
Flat races ...	200	...	500,000	
Hollow races	200	from	1,000,000	when the radius of the race is about twice that of the ball.
		to	1,250,000	when the radius of the race is 9/16ths that of the ball.

For journal bearings:—

	C.		K.	
Flat races...	2,000	...	1,000,000	
Hollow races	2,000	from	2,000,000	where the radius of the race is about twice that of the ball.
		to	2,500,000	where the radius of the race is about 9/16ths that of the ball.

The question of roller-bearings was first dealt with. When an elastic roller rolled on an elastic bed there was always slipping, the amount of this slipping depending very largely upon the load, *i.e.*, there was a small amount of slip with a very light load, and a comparatively large amount of slip with a heavy load. In the case of roller bearings end thrust resulted in the rollers wearing right through the end of the cage, and in addition setting up a vibratory action on the bearing, which enormously increased the friction of the bearing. End thrust, he pointed out, might easily amount to a quarter or a third of the total load on the bearing. With a 10-ton load on a bearing, from 2½ tons to 3 tons end pressure would be encountered, and the direction of the end thrust always reversed when the direction of rotation of the shaft was reversed. He mentioned a case where 40 or 50 railway wagons were fitted with roller bearings which had to be put out of service owing to the amount of end thrust, which in some cases had worn right through the casing. This end thrust with roller bearings occurred however good the workmanship, although one form of roller bearing in which the length of the roller was approximately equivalent to the diameter, the end thrust was almost absent. The lecturer referred to the satisfactory service given by the plain roller bearings used on light railway wagons of the Koppel type, the bearings being practically pieces cut off mild-steel rods with the ends rounded. The results obtained with this cheap form had, curiously enough, been found to be almost equal to the most expensive type of roller bearing. The tests showed that better results were achieved with long rollers; but these, he remarked, could not be regarded by any means as an unqualified success.

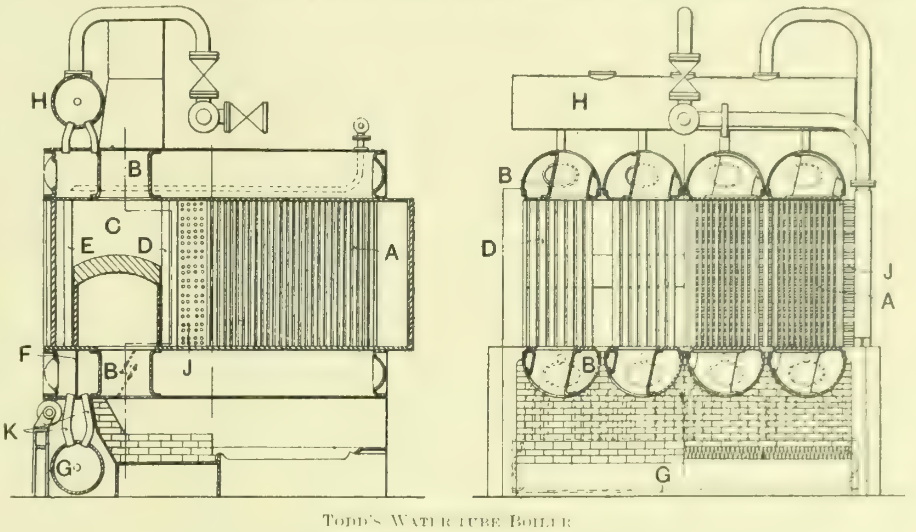
Prof. Goodman stated that with a properly-designed roller bearing in which the end thrust was extremely small, the friction was to all intents and purposes independent of the

lubrication; but when a large amount of end thrust manifested itself, then lubrication made a very considerable difference, for the simple reason that when there was little end thrust a pure rolling action was obtained, whereas with end thrust there was a large amount of friction between the ends of the cage and the flange of the casing. In these instances lubrication did good. Friction with roller bearings had been determined to be almost independent of the speed, and in all roller bearings, bad and good, the starting effort was very little greater than the running effort, which was admitted to be a point in their favour for machinery constantly starting and stopping. With the worst type of roller bearing the friction was lower than in an ordinary bearing with poor lubrication; but a roller bearing in these conditions was not so good as a bearing running in a bath of oil.

Turning his attention to ball bearings he pointed out that there was no end thrust at all, and the friction was very much less than in the majority of roller bearings; hence there was a good deal to be said in their favour. It might be said against this statement that a ball bearing bore only on a point, whereas the roller bearing bore on a line; hence a ball bearing of a certain size could not possibly carry so high a load as a roller bearing. There was, he admitted, an element of truth in this, but it was not the whole truth. With equally good material in rollers and balls, and in the absence of end thrust on the roller bearing, the argument would hold rigidly; but since end thrust did come in with the roller bearing, with other troubles in consequence, practically any type of ball bearing was able to carry a much bigger load than the roller bearing. In the case of ball bearings it was essential that the balls and the ball races were made of high-class material and with a sufficient degree of accuracy. This was obvious from the fact that the difference of a thousandth of an inch in diameter between balls in the same bearing resulted in an extra load of about 200lbs. being placed on the larger ball. The wear of ball bearings in the case of a properly made bearing was, he stated, practically nil. After running ball bearings for 15 years' continuous work he had only had half-a-dozen actually break in the testing machine. Practically all the failures were due to the peeling of the surface of the ball, due to overloading. Ball bearings required practically no lubrication—certainly not more than once in two or three months, and then merely to prevent rust. If rust could be prevented a ball bearing would run just as well without oil as with it.

TODD'S WATER-TUBE BOILER.

THE accompanying sectional views show a construction of water-tube boiler designed and patented by Mr. David R. Todd, 39 and 40, Arcade Chambers, St. Mary's Gate, Manchester. Each element of the boiler comprises upper and lower vessels connected by vertical water tubes A of small diameter. These vessels are semi-cylindrical and identical in construction, the opposing flat surfaces forming tube plates, into apertures in which the ends of the vertical water tubes are secured. These elements extend lengthwise of and above the furnace chamber. The rear portion of the lower vessels is supported on a roller in the boiler casing, so that the whole element is free to expand at that end. Through both the lower and upper vessels an aperture is formed near their rear ends. Short lengths of pipes are secured in the vessels by flanges on their ends extending around the circumference of the apertures, these pipes forming flues B by means of which the fire gases pass to and from a combustion chamber C. By setting the flue pipe B towards one side in the vessels, as shown, sufficient space is provided in these vessels for a man to pass the flue pipe B. After the fire gases pass through the flue B they enter the combustion chamber C at the rear of the boiler, this chamber being a space between front and back walls D, E of vertical water tubes. These tubes are of relatively larger diameter than the other water tubes A and they also extend between the upper and lower vessels. The back wall tubes E communicate at their upper ends with the rear of the upper vessels, and at their lower ends with a space at the rear of the lower vessels, partitioned off by a removable diaphragm F to form a depositing chamber, which is in a position most remote from the furnace. These tubes E are lagged or protected by brickwork from the action of the fire gases. A mud drum G extends transversely beneath the depositing chamber, and it is connected to the lower vessels by a double row of tubes K, so designed as to permit of considerable flexibility. The removable diaphragm F extends between the upper ends of the two rows of tubes, so that the back row acts as down-comers, and the front row supplies water, freed from sediment, to the lower vessels. A steam drum H extends transversely above the rear of the four elements, being connected to each of the upper vessels by flexible tubes. Between the front wall D of the larger tubes and the smaller water tubes a space is also left. This space is provided to receive a superheater in the form of horizontal rows of U-shaped tubes J, the length of these tubes being preferably such that they extend across two of the elements.



TODD'S WATER-TUBE BOILER.

The combustion chamber C is arched over as shown at about half its height, and after the fire gases reach that chamber, they are directed by partitions towards the front end of the boiler, over the tubes of the two central elements only. The gases divide at the front of the boiler, one half of the total quantity passing backwards over the tubes of each of the two side elements, the gases then uniting in the part of the combustion chamber which is above the arch and passing out through the upper flue B to the uptake, which is over that flue.

The circulation in the boiler takes place from front to back, the tubes A D above the part of the lower vessels which is over the furnace, acting as upcomers, the discharge of steam from such lower vessels passing mainly through the relatively large tubes D, thereby reducing the wear and tear on the other and smaller tubes A. The tubes E at the rear of the combustion chamber C act as down-comers, the down-comer streams of water passing from the depositing chamber in the lower vessels through the tubes K to the lower mud drum G, and the lower vessels being fed with water freed from sediment through the front row of the tubes K, connecting the mud drum with these lower vessels. The feed water is introduced into the upper elements by internal feed pipes connected with a supply pipe, the water being discharged immediately above the down-comer tubes E thus assisting the descending stream and also allowing any solid matter which the feed water may contain to fall into the depositing chamber and mud drum G.

Personal.—Mr. John F. McIntosh, M.V.O., after a service of 52 years with the Caledonian Railway Company, has decided to retire from active service in May next. Mr. W. Pickersgill, of the Great Northern of Scotland Railway, has, we understand, been appointed to fill the vacant position.

SOME CAUSES OF INJURY TO STEEL AFTER MANUFACTURE.*

BY CECIL H. DESCH, D.SC., PH.D.

(Concluded from page 607, Vol. XXXII.)

Cold-Working.— Passing now to the effect on structure of cold-working, that is, of subjecting the steel to mechanical deformation at a temperature below that at which recrystallisation takes place spontaneously, it may be said that the nature of the change is no longer doubtful. The first yielding of steel, as of any crystalline solid, takes place by slipping of particles over one another along innumerable gliding planes—a change which can take place without any destruction of the crystalline structure. As the deformation becomes more severe, however, a limit to the possible amount of slipping is reached. The stresses in individual crystals become intensely localised, and the remarkable researches of Dr. Beilby have left little doubt that the metal surfaces, where slipping has taken place, undergo a change, the crystalline material being converted into one which is amorphous, hard, elastic, and brittle, like glass. A metal hardened by work, a metal with remanent interstrain, is one in which a part of the crystalline material has been replaced by the amorphous modification. When the cold-working is severe, each small mass of crystalline metal is enclosed in a hard shell of amorphous material, in which gliding planes cannot be formed. Hence the increased hardness and elasticity, and lessened ductility of the worked metal. By increased elasticity is here meant a raised elastic limit, so that the hardened metal will bear a higher load without permanent set than the unhardened. Within the elastic range, however, the modulus of elasticity is unaltered, so that a steel wire, for example, stretches to the same extent, whether in the hard-drawn or the annealed state, provided that the load does not exceed the elastic limit in either case.

A cold-worked metal has a lower density than the same metal in the annealed state. The contrary statement is sometimes found in text books, but the reduction in density is well established by careful experiments. It must not be confused with the increase of density observed on hammering or rolling cast metal, which is merely due to a mechanical closing up of pores and gas cavities. This change in density is in accordance with the hypothesis of the amorphous modification, which has the properties of a glass or under-cooled liquid, and it is an essential property of such under-cooled liquids that they are normally less dense than the crystalline solid forms of the same substance. The behaviour of the two modifications towards corrosion is mentioned later.

Local cold-working occurs wherever a part of the metal is mechanically deformed without the remainder being similarly affected. For example, the sheared edge of a plate is in a different physical condition from the neighbouring metal. A good example is that of a punched hole. Punching involves extremely severe deformation. Fig. 15 is a photomicrograph of the steel punching from a plate, an area very near to the circumference being shown. The bands of ferrite and pearlite are extremely distorted. The further change, the conversion of crystalline into amorphous material, is not to be recognised in the photograph, but affects the properties of the steel in a remarkable manner.

There is thus, immediately surrounding every cold-punched hole, a layer of steel of distorted structure, with increased hardness and elastic limit, and diminished ductility. When a stress is applied to the plate, its distribution is affected, not only by the presence of the hole, an effect which may be calculated for a homogeneous material, but by the presence of a ring of heterogeneous material, the effect of which is to localise stress still further. This deformed layer is of only microscopic thickness when the hole is drilled instead of being punched, as the drill cuts in such a way as to produce very little deformation. For the same reason, the deformed metal may be completely removed by reaming, provided that the process is carried sufficiently far, the necessary depth depending on the thickness of the plate.

A few more instances of local cold-working may be given. A steel bottle containing carbon dioxide under pressure exploded on being allowed to fall and striking the ground with the neck.† The bottle was of mild steel, rather unequal in thickness, and had been heavily stamped just at the shoulder with an official letter stamp. It was at this point that fracture took place, and microscopical examination showed that the steel had a cold-worked structure extending to one-sixth of its depth. The steel was thus doubly weakened at this point—first, by the indentation caused by the stamp, which would have the effect of a notch, and secondly, by the deformation of the underlying material, causing heterogeneity of structure and properties. This double effect of a stamp is of great importance, as it may easily lead to unexpected failures in plates when used in structures liable to severe stresses or to fatigue.

Steel rails are not liable to severe deformation in ordinary use, the slight spreading of the head which takes place being unaccompanied by severe hardening. Where, however, brakes are applied sharply, and rolling is replaced by sliding, very severe local cold-working may occur, and a layer of hard material, in which cracks readily occur, is formed at the surface of the rail. A similar condition has been met with in tender tyres, which were found to exhibit scaling.‡ Microscopical examination showed the steel to be quite normal, but near the wearing surface the structure was greatly deformed, owing to severe braking under a heavy load. The hypothesis of an amorphous modification also explains, in a most satisfactory manner, the phenomena of fatigue.

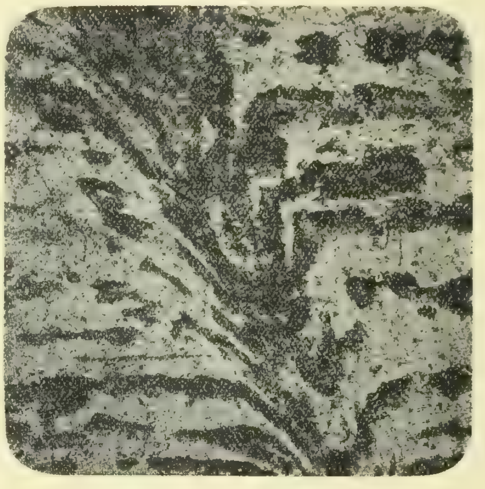


FIG. 15.—DEFORMED LAYERS IN STEEL PUNCHING.

Welding. — The term "welding" is now somewhat loosely applied. Meaning originally the union of two pieces of metal within their plastic range, but below their melting point, as in an ordinary blacksmith's forge weld, it has been applied, in the form "autogenous welding," to denote a process of union by fusion, either of a part of the metal to be united or of a separate piece of metal used as a solder. Such a process is really one of autogenous soldering, not of welding.

The ideal condition to be reached in a weld is that in which the crystals are continuous from one side of the weld to the other, and there is no change in the average dimensions of the crystal grains in passing through the weld. This condition necessitates the complete absence of intervening layers of impurities, especially of oxides, and also the absence of a zone of overheated metal.

In true welding, which can take place at as low a temperature as 800°, but which, of course, proceeds much more rapidly and certainly at higher temperatures, there is mutual interpenetration, and, if oxidation is completely prevented, there is no reason why the weld should be weaker than the remainder of the metal. In practice, the weakness which is so frequently observed is due to incomplete union, as is readily seen under the microscope.

The conditions are somewhat different when any of the high-temperature methods of autogenous soldering are applied. The microscopic structure of such welds has been described, and illustrated by excellent photographs, by Messrs. Law, Merritt, and Digby.§ In electric-resistance welds, the presence of oxide is to be clearly traced along the

* Paper read before Institution of Engineers and Shipbuilders in Scotland, October 21st, 1913.

† C. von Bach, "Stahl und Eisen," 1912, 32, 1111.
‡ O. Bauer and E. Wetzel, "Stahl und Eisen," 1911, 31, 226.
§ Journal Iron and Steel Institute, 1911, 31., 103.

plane of union, and a zone of very coarse crystallisation is obtained. The process of autogenous soldering with a blow pipe flame introduces new conditions. Should the flame contain an excess of oxygen, oxide films are produced, whilst with acetylene, the latter being in excess, a carburised layer may be formed. In either case the join is bordered by a zone of coarse, over heated metal. In welding by means of a carbon arc, local carburisation is still more apt to take place, whilst union is often extremely local. There remains the process of thermit welding, in which the two pieces of steel are united by a layer of almost pure molten iron, which alloys perfectly with the adjoining metal. Here, also, recrystallisation goes on in the immediate neighbourhood of the join, but to a less extent.

The evil effect of over-heating may be largely removed by hammering or forging the weld, followed by a short annealing process. Annealing alone is not usually successful. Imperfect union through the presence of gas cavities or inclusions of slag or oxide, and heterogeneity due to a highly carburised zone, are defects which are not removed by subsequent treatment.

The author has no intention whatever of suggesting that autogenous soldering is a process to be condemned. On the contrary, it has a wide field of usefulness, and is, in fact, a technical necessity for certain classes of work. It must be admitted, however, that a joint made in this way has not the same qualities as the original steel. It is not sufficient to show that fracture does not commonly take place in the plane of union when a mechanical test is made. It is not the weld, but the zone immediately adjacent to it, which is injured. Neither are tensile tests conclusive on this point, as the injury to the steel does not always affect the tensile breaking strength, but is revealed when the welded steel is subjected to shock or fatigue. Accounts have been published of boilers which have cracked in numerous places in the course of use, and repaired by autogenous soldering. Where it is intended to use the same pressure as before, and to regard the plates as retaining their original strength, such a practice seems very undesirable. A systematic series of fatigue tests on such repaired plates would be interesting.

Corrosion. — It is not intended to discuss the general question of corrosion, but merely to indicate the manner in which it is influenced by some of the factors already mentioned. The influence of cold-working may be considered first. A cold-worked metal contains a larger amount of energy than one in the fully-annealed condition, and this energy reappears as heat when the metal is dissolved, or as electrical energy when the conditions for an electrolytic couple are present. If a cold-worked and an annealed specimen of the same metal are connected together in an electrolyte, the former in general becomes the anode. The effect is easily seen by taking a length of soft steel wire, lightly hammering one-half of it, and then immersing it in Walker's ferroxyl reagent. A blue area is formed around the hammered portion, and a red one around the untreated portion. This condition presents itself wherever steel has been locally cold-worked. Thus, a punched rivet hole, with its enclosing zone of deformed metal, acts as a centre for corrosion. The sheared edge of a plate also corrodes more rapidly than the neighbouring metal, although in such cases as this it is difficult to distinguish between effects due to cold-working, and those due to the removal of a protecting layer of oxide. Wherever cold worked and unworked metal are in contact, the possibility of an electrolytic couple exists, and when the metal is brought into contact with an electrolyte, corrosion is accelerated.

The fact that steel plates, as received from the manufacturer, are covered with a thin, firmly-adherent film of the magnetic oxide is of importance in this connection. If the plate is deformed by the application of stress, say by tension or by bending, the oxide film cracks, and the lines known as Lüder's lines may, in fact, be mapped in this way. At each crack the underlying metal is exposed, and as the electrochemical difference between steel and the magnetic oxide is considerable, corrosion is likely to start along those lines. It is not even necessary that the deformation of the steel should have exceeded its elastic limit. Alternating stresses, well within the elastic limit of the steel, will suffice to crack the relatively inelastic film of oxide, and the appearance of parallel grooves of corrosion in the interior of boiler plates has been traced to this cause.

Lastly, reference may be made to some effects of galvanising on steel. The protective coating of zinc, being more strongly electro-positive than steel, corrodes preferentially. The coating is not, however, an entirely distinct layer, like a paint, but is chemically united to the steel by an intermediate layer of an iron zinc alloy. The microscope shows, in this layer, very conspicuous crystals of the compound FeZn, which is less electro-positive than zinc. Hence if the outer layer of zinc be removed by solution or abrasion, these crystals (Fig. 16) are exposed, and accelerate the corrosion of the neighbouring zinc. Beneath this layer is another, richer in iron, and corresponding with the formula $FeZn_3$. This compound is not only more electro-negative than zinc, but even than iron, and, if exposed, accelerates the

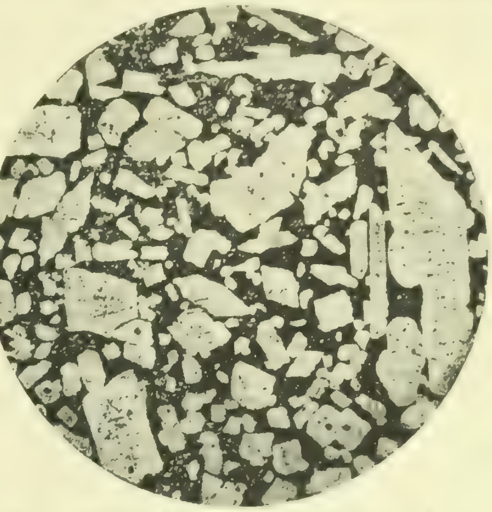


FIG. 16.—CRYSTALS OF COMPOUND OF IRON AND ZINC.

corrosion of the steel instead of retarding it. This accelerating effect is still greater in the case of steel coated with zinc by the sherardising process, in which zinc vapours take the place of a bath of molten metal. The transition from $FeZn_3$ to steel is more abrupt, so that the protecting layer cracks more readily, and sets up local electrolytic couples. Coating with zinc by electrolysis—a process little used in this country does not give a layer of an intermediate compound, as the temperature of the process is too low for the necessary diffusion. It is probable that the process, recently introduced but now increasingly employed, of coating by means of a very finely-divided metallic spray, would not result in the formation of a compound.

The increased brittleness of galvanised steel, as compared with the uncoated metal, is accounted for by the presence of the crystals shown in Fig. 16. These crystals are extremely hard and brittle, and their presence in the outer layer of the steel has the effect of localising stresses, and so of facilitating fracture under conditions of shock or fatigue.

These brief notes deal only with a few of the possible sources of injury to steel subsequently to its manufacture. A complete review of the subject would demand a wide experience of the handling of steel under different conditions. Many of the injuries are only observed in repairing yards, or in the course of inspection, and frequently escape permanent record. All that the writer can hope to do is to suggest, by a few examples, the nature of the assistance that metallography is able to afford, first in elucidating the cause of an injury, and then in indicating the treatment by which such injury may be remedied or prevented. The microscopical and thermal study of metals is a fascinating subject in the laboratory, but it has the advantage over many other laboratory studies, that its conclusions are often immediately applicable to the needs of industry, whilst even the most purely scientific investigations into the molecular constitution of metals are found, in course of time, to bear on problems of practical interest and social utility.

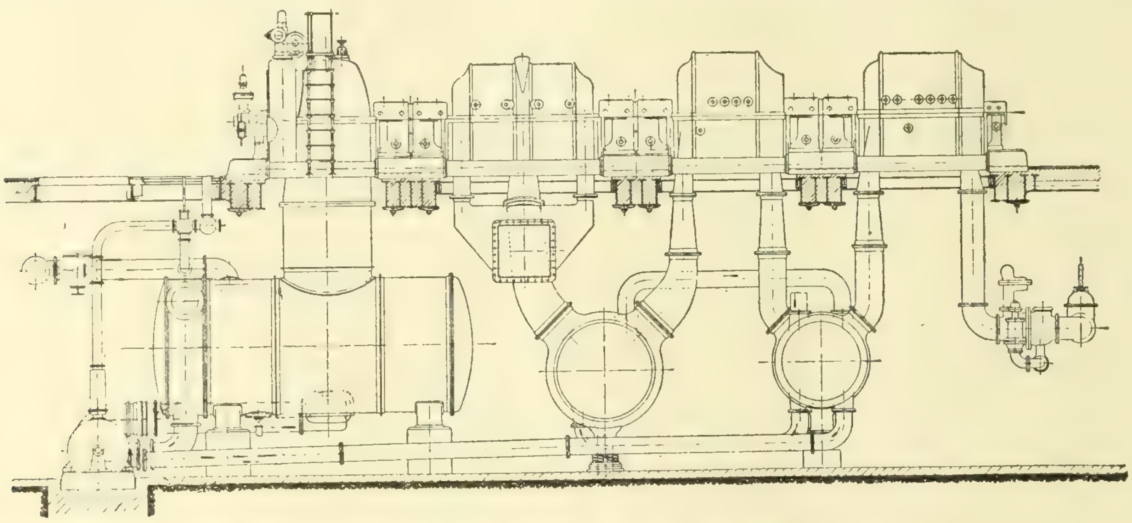
Status Prize.—The Council of the Society of Engineers (Incorporated) may award in 1914 a premium of books or instruments to the value of £10 10s. for an approved essay on "The Status of the Engineering Profession." Detailed particulars may be obtained from the Secretary, 17, Victoria Street, Westminster. The last date for receiving essays is May 30th, 1914.

LARGE TURBO-COMPRESSORS.

An interesting example of the rapidity with which a new type of machine is brought from the initial stages to a practical and serviceable form in modern machine construction is found in turbo-compressors. The development of the reciprocating steam engine, from the time of James Watt down to the modern high-speed steam engine, occupied a period of about 100 years, and the steam turbine—if the year 1883 be regarded as the date of its birth—has required 25 years to reach its present stage of perfection; the turbo-compressor, however, which is to-day constructed in single units for the largest outputs, has been developed within a period of about 10 years. The turbo-compressor permits the construction of air-compression machines for the very highest outputs such as were hitherto regarded as unattainable, and thus enables compressed air to be generated very much more cheaply than was formerly the case.

An interesting example of a large turbo-compressor is shown in the accompanying illustration, reproduced from the "A.E.G. Journal." This machine, which was recently constructed in the workshops of the A.E.G. turbine factory, Berlin, is capable of delivering the enormous quantity of 100,000 cbm. of air per hour at a pressure of 140-170lbs. per square inch, this output corresponding to a power input of 12,000 h.p. to 13,000 h.p., measured at the shaft. On the left hand of the illustration the steam turbine is visible; the machine is designed for the use of high-pressure and superheated steam, and is fitted with automatic nozzle regulation and a horizontal valve rod mounted above it. This is the first turbine built to give an output of 12,000 h.p. at a speed of 3,000 revs. per minute. The compressor, consisting of three cylinders, is connected to the steam turbine by a flexible coupling. The low-pressure cylinder lies next to the turbine, and, in view of the large quantity of air, is constructed to draw in air on both sides. The air passes from the main suction pipe of square section into the two ends of the low-pressure compressor, passing out again in a slightly compressed condition through the spiral pressure pipe. In consequence of the compression its temperature has now risen to about 100° C., and at this temperature it is led to an intermediate cooler lying below the compressor, in which it is cooled down to about 30° C. The medium-pressure cylinder through which the air next has to pass is constructed for inhaling on one side only, as the volume of air has been reduced here to such an extent that it is no longer necessary to divide the air current on account of the section of the impellers. The air compression is further increased in this cylinder, and the air passes out of it in a highly-heated condition to be cooled again in a second cooler, whereupon it then enters the high-pressure cylinder, in which it is brought to the specified final pressure, and is finally led to the point of use through the pressure pipe on the right. As the cooling effect in the intermediate coolers is not sufficient to permit the process of compression to be carried out economically, the compressor cylinders themselves are continuously cooled with cold water.

The compressor plant described is to be supplied to the Victoria Falls and Transvaal Power Company in the Transvaal, which placed an order with the A.E.G. for three compressors giving the above output in autumn of the previous year. This power company was the first to avail itself of the advantages of the turbo-compressor when constructed in large units, and to adopt the transmission of power in the form of compressed air on a large scale. The company already has twelve 4,000 h.p. turbo-compressors in commission in its power stations situated close to Johannesburg, eight of which were built by the A.E.G. The compressed air generated by these machines is transmitted through a pipe-line 30 km. in length and supplied to 17 different mines, in which it is employed for rock drills and other compressed-air tools. After the three new compressors referred to above have been placed in commission the total amount of energy transmitted in the form of compressed air will amount to 84,000 h.p., an output which would scarcely have been practically possible with reciprocating compressors. The first 12,000 h.p. compressor passed on to the test-bed of the A.E.G. turbine factory a few months ago for testing purposes, where it satisfied the guarantee conditions for steam consumption. The plant was allowed to run on the test-bed for several hours with a load up to 12,000 h.p. corresponding to the normal working conditions.



Large Turbo-compressor for the Victoria Falls and Transvaal Power Company.

STEAM GENERATOR FOR GAS PRODUCERS.

An apparatus for producing the necessary steam for the working of gas producers has been put on the market by Bender & Främbs, of Hagen, in Westphalia, and has found quite an extended use in iron, steel, zinc, and other metallurgical works in Germany. The arrangement of the apparatus is shown in the cuts herewith, for which, along with the fol-following description, we are indebted to "The Iron Age."

A small amount of gas from the producers is tapped from the gas main at *d* and burned in the combustion chamber *a*. The hot gases are drawn through the evaporating chamber *b*, located near by, in which they vaporise and convert into steam as much water as is necessary for the operation and production of a good gas. The ventilator *c* (of 3 h.p. to 4 h.p. for a 10-ton producer) forces into the gas producer the mixture of the products of combustion with the steam and the air, whose temperature is about 150° to 170° C., and whose carbon dioxide content is about 1 to 1·50 per cent. It is evident that a mixture heated as highly as possible prevents any condensation in the steam, so that actually only the least amount of steam necessary for the operation of the producer need be formed. A temperature of over 100° C. prevents the formation of sulphurous acid, and consequently the corrosion of the pipes. In using saturated steam it is figured that 1 kg. of gasified coal requires from 0·4 to 0·5 kg. of steam, while a temperature of the mixture of 150° to

170° C. reduces the necessary steam to 0·25 to 0·30 kg. without the formation of large lumps of slag. But the presence of small, brittle lumps of slag ensures a quiet, even opera-

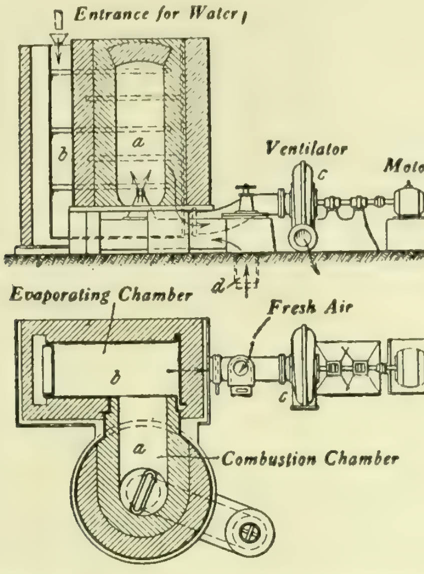


FIG. 1—SECTIONAL VIEWS OF STEAM GENERATOR FOR GAS PRODUCERS.

tion of the producers, which makes itself manifest in a reduced coal consumption, even though a part of the saving in coal is neutralised in drawing off some of the producer gas for the evaporator. The accompanying table gives some figures collected during a five months' operation of a 10-ton gas producer with a vaporiser. They show that a gas producer plant can be very profitably operated with its own vaporising or steam-producing apparatus. The advantages consist in the following: Independence from a boiler plant—a saving in wages as well as coal for the boilers; a regular and uniform operation of the producers, with greater certainty of uninterruption, and continuously good gas.

Table Showing Results of Five Months' Operation of Steam Generator for Gas Producers.

Conditions of Operating.	CO_2 per cent.	CO per cent.	CH_4 per cent.	H per cent.	Approximate heat value in heat units.	CO_2 content of the gases from the vaporizer in per cent.	Amount of water vaporized, cbm.	Temperature in Deg. C.: Of the product of combustion + the steam.	Of the fresh air admitted.	Of the mixture before its entrance into the producers.	Production in 24 hours, tons.
1. Without the vaporizer, but with a Körting blower	4·9	25·2	2·5	11·4	1335·5	-	3·80	-	-	--	9·5
2. With the vaporizer and with the admission of cold fresh air	4·2	27·0	2·3	12·1	1391·5	1·3	2·70	290	15	165	9·0
3. With the vaporizer and preheated fresh air	4·0	27·2	2·4	14·1	1467·0	1·3	2·61	290	100	250	8·7
4. With the vaporizer and preheated air, but diminished quantity of water	3·8	28·1	2·6	12·3	1459·0	1·4	2·10	300	110	270	8·4

(Columns 2–6: Composition of Generator Gases.)

The International Testing Association.—A meeting of the British Section of the International Testing Association was held in the offices of the Iron and Steel Institute, London, on December 18th. The British Section consists of all members who pay an annual subscription of one guinea, and of representatives of bodies which give subventions to the association. Since paucity of members is one of the chief causes of the small influence exercised by the British Section, the desire was expressed that such bodies should nominate several representatives, and not one only. It was resolved that the committee of management should consist of the British Member of Council of the association, a chairman, vice-chairman, and 15 members, to be appointed by co-option of the actual organising committee. The next congress is to assemble at St. Petersburg in 1915, and a new committee is to be elected by a general meeting within four months after that congress. Another general meeting is to be held within six months before the next congress.

TASK SETTING FOR FIREMEN AND MAINTAINING HIGH EFFICIENCY IN BOILER PLANTS.*

BY WALTER N. POLAKOV

(*Concluded from page 610, Vol. XXXVII.*)

THIS general outline of a method of analysing the limiting values of variables and determination of conditions necessary for the attainment of certain predetermined results would be incomplete without a reference to the practice of studying the influence of individual variables. The writer is convinced that any boiler trial conducted with the most scrupulous care may leave obscure the influence of a number of the above-mentioned limiting factors as well as leave the question uncertain whether the maximum practical efficiency or capacity was really obtained during the test and whether or not the various conditions as observed are necessary and sufficient to duplicate the results at any time. The writer maintains, that as long as the question is not to attain accidentally a mark set at random, but clearly and fully to determine all conditions necessary for maximum economy of operation for the purpose of setting definite standards, it is imperative to conduct a number of separate observations, though of short duration, dealing in each case with one and only one variable in order to find its limiting effects. Only through an *a posteriori* method of reasoning, through a wide induction from a sufficient number of particular observations, may the probability that is tantamount to certainty be attained.

Ascertaining finally the physical elements of the efficiency equation and its value and eliminating the constants beyond our control, we ultimately obtain a reliable basis for judging the efficiency of the "human element" of the problem which could be expressed as

$$E_m = f\ (e)$$

and its limit is reached when the difference between the theoretical efficiency of the process and its actual accomplishment is zero.

We now come to the question of how to use this available knowledge based on theoretical research in such a way as to secure the best results practicable in regular service by the task method. In setting a task for firemen, it remains to be determined what the scope of the task shall be. In order to accomplish the purpose it devolves upon the management to accumulate the detailed and exact knowledge of the most favourable conditions to attain results and make it possible and desirable for every employé to live up to them. It is for the employé, on the other hand, either to create or maintain such conditions as are required in the management's specific instructions.

Various schemes have been used as the basis of task setting for firemen which to the writer's knowledge have always created dissatisfaction. Certain of these are as follows: (*a*) The cost of steam generated was used for the basis of the task in the boiler room of a large cement plant, and a premium offered for the reduction of this cost, but as firemen have no control over the purchase of fuel, maintenance of equipment, &c., this task involved the standardising of conditions of combustion, for which no instru-

* Abstract of paper read before the American Society of Mechanical Engineers.

ments were provided and no definite standard or aim was set before them, and the scheme was soon abandoned. (*b*) The high percentage of CO_2 in flue gas was adopted as a task basis for firemen in several plants, but the men were not trained nor were they even shown how to obtain it. When they occasionally attained the mark, the question remained undecided whether high percentage of carbon dioxide was coincident with the most economical steam generation or not, and the method proved generally unsatisfactory. (*c*) A high percentage of CO_2 and low percentage of combustible in the ashes, were factors upon which another attempt was made to specify more definitely the firemen's task. The question remains, however, whether the conditions which the firemen must observe to attain the task and produce gas rich in carbon dioxide and an ash with little carbon, are actually the best for transmitting the heat of the gases to the water and steam and whether at any load the same standard is equally beneficial. (*d*) A limit on coal consumption as a task for railroad firemen was favoured at one time. This idea, probably the most ridiculous and illogical, soon demonstrated its own weakness and has been almost entirely abandoned.

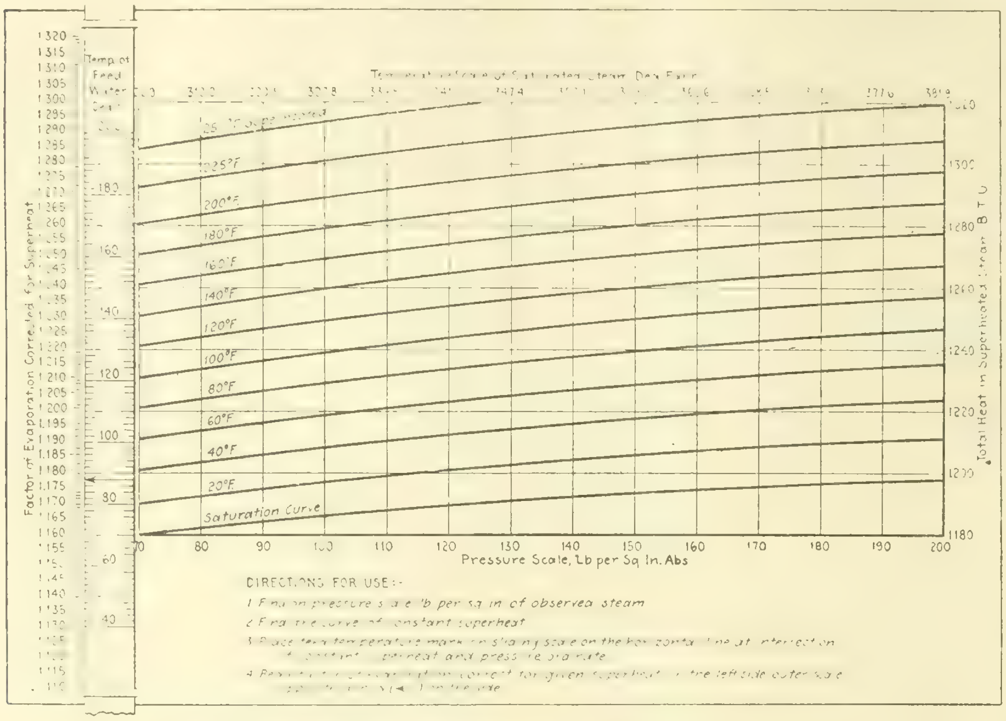


Fig. 3. Slide Rule Used for Determination of Factors of Correction.

The lack of analytic thought in these instances is remarkable; such important factors as condition of equipment, variable quality of fuel, weather conditions, necessary instruments, complete record keeping, thorough instructions, &c., were disregarded or undervalued. The common cause of failure of such schemes has been the desire to make a short cut and jump over all preliminary studies, and save the time and trouble of training men in a systematic and thorough manner how to accomplish the task set for them. Should such training be undertaken with bona-fide intentions, the instructors themselves would be compelled to discontinue the training as soon as they discovered that the control of the conditions affecting the results is beyond the men.

The question of measuring the effect of task accomplishment can be approached from either end, but it is more convenient to figure out the result, and if this is below the standard, turn to the records of conditions and there locate the discrepancy between the required results and those obtained. A gauge for measurement of the degree of fulfilment of task conditions set is offered by the factor of thermal efficiency of grate, furnace, and boiler which is

$$\frac{\text{heat transferred to steam}}{\text{heat available in fuel}}$$

This measurement involves several corrections for factors beyond firemen's control, and neither ratio of apparent evaporation nor boiler efficiency nor efficiency of combustion alone are anywhere near sufficient for the purpose of judging the efficiency of the work of men.

Actually to calculate the efficiency of the boiler, furnace, and grate is a tedious and comparatively long procedure, and is never made in power plants for a day shift, fireman, or gang of firemen, working in team. The writer in his capacity of consulting engineer devised and introduced a comparatively simple method of obtaining a complete record of firemen's performance and to figure their efficiency. This method requires the following record data: (*a*) Coal records from store issue tickets and coal passers' reports compiled every eight hours; (*b*) heat value of fuel determined by bomb calorimeter and value of coal in B.Th.U. known for each coal pocket; (*c*) amount of water fed to boiler (banked boilers fed separately) ascertained for the same periods; (*d*) temperature of feed water recorded; (*e*) steam pressure recorded; (*f*) degrees of superheat recorded.

These data are turned over to the station clerk, who proceeds as follows: (*a*) From the slide rule shown in Fig. 3, he ascertains the factor of evaporation (corrected) on the basis of absolute boiler pressure, temperature of feed and temperature of superheat; (*b*) by means of the power plant log calculator, Fig. 4, he determines (1) actual evaporation ratio during each watch or per each man, (2) factor of evaporation during each watch or per each man, (3) equivalent evaporation during each watch or per each man, (4) efficiency of steam generation per watch or per each man, (5) cost of fuel per 1,000lbs. of steam per watch or per each man.

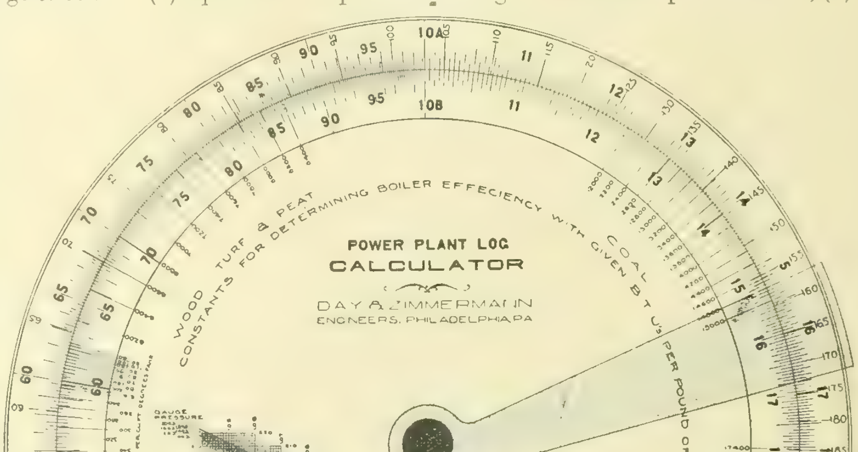


Fig. 4. Power Plant Log Calculator.

He then enters the results of computation on the daily power plant report form (see Fig. 10). The whole procedure takes on the average 18 minutes of the clerk's time, for whom, incidentally, a specific task is assigned and sufficient hourly bonus offered for its fulfilment.

Every case of failure on the part of any fireman to secure on his watch the combined boiler, furnace, and grate efficiency of 70 per cent. or above is immediately investigated by studies of other records and recording charts of draught, temperature of escaping gases, nature of boiler refuse, &c., and if no reason can be found there, an examination of the physical condition of equipment and apparatus is made. The result of this investigation is recorded on a form for cause of lost bonus, Fig. 5. This method is particularly valuable, and outside of its direct advantages provides an additional and continuous training of the men in careful observation of harmful factors of the slightest nature.

9 6 1913
MONTH DAY YEAR

I HAVE INVESTIGATED AND REPORT BELOW THE
CAUSE OF LOST BONUS

DEPT *Electr*
DISTR *War. Ridge*

BY *O. Hawn* ON JOB *Firing*

CONDITION *Draft was set wrong*

Due to leak in draft gauge

RESPONSIBILITY IS ALLOCATED TO *Maintenance Man*

REMEDY ATTENDED TO BY ME *Ordering Repair*

S. D. Port
SIGNED

FIG. 5. FORM USED FOR RECORDS OF CAUSE OF LOST BONUS.

Then by means of complete and trustworthy records the firemen are informed as to results of their work before they come back for the next watch, see Fig. 6, and moreover, while they are proceeding with their work, they have in addition to previously mentioned instruments indicating the condition of firing, continuous information as to results they are accomplishing up to any moment of their watch. This is accomplished by having coal weighing and water metering so balanced that an even number of dumps of feed water and dumps of coal indicates that the ratio of evaporation (superheat, pressure, and feed temperature being as specified) is on the safe side of the requirement.

The record of attainment of the task by firemen kept in the manner devised by H. L. Gantt, Fig. 7, offers many advantages over any other method. The illustration of this record, kept from the start of task work in the boiler house at Warrior Ridge of the Penn Central Light and Power Company, shows steady improvement and better habits of men. While the May record showed only 68·7 per cent. efficiency of boiler and grates of the whole plant, the last month on this record showed the efficiency of 75·1 per cent. The number of daymen falling short on the task is steadily reducing. The number of men absent is, however, chiefly due to "days off" and summer vacations, for the men work seven days a week in a plant of this character. It should here be stated that the departure from the principle of separate man's record made by the writer at first involuntarily proved to be so gratifying, creating as it did an unusually strong team spirit of co-operation, that the writer has never attempted to split the records of two or three men working jointly firing one battery of boilers.

The elements affecting the choice for or against task work are so numerous that they cannot all be mentioned. The essential thing is that some element of advantage to the workman be introduced sufficient to overcome actual or imaginary disadvantages believed by the men to exist as a result of the new state of affairs. This advantage takes the form of a sufficiently attractive and generous bonus to be paid for willingness to learn the new way and to continue to observe the instructions. Actual accomplishment of the task and consequent earning of the bonus means the adjustment of certain conditions concurrent with the adjustment of others. This adjustment being under the control of the employé is a physiological process principally depending on (*a*) the will-power of the man, and (*b*) physical fitness.

DAILY BONUS SLIP CHARGE

DATE *September*

NAME *J. Dearing* NO

DISTRICT-PLANT *Warrior Ridge*

HOURS DAY WORK *4*

HOURS BONUS WORK *4*

HOURS BONUS EARNED *1*

TOTAL HOURS FOR DAY *9*

REMARKS *71.8% - 4 hrs. firing on 3rd shift.*
4 hrs passing coal for sick coal passer.

SIGNED *S. D. Port*

FIG. 6. FORM FOR DAILY BONUS STATEMENT TO FIREMEN.

As a rule, the workmen feel that the adoption of a new method will impose an undue strain, but it is comparatively easy to overcome this misconception with the firemen from the fact that greater efficiency means less coal to be shovelled.

In order to determine the amount of bonus, there must be two limits established—a maximum and a minimum. The maximum bonus should be equal to the amount of net saving accomplished under given circumstances, while the minimum bonus is, of course, equal to zero. When the bonus to be paid actually reaches either of these limits it loses its usefulness since it loses its stimulating effect—with the management, if the maximum, and with the men, if the minimum. Since in an average boiler house the task results in about 25 per cent. saving on the coal bill while the firemen's pay roll is from 10 to 15 per cent. of the coal bill, it is evident that there is a considerable latitude for adjustment of bonus. After the choice has been made in favour of task work, however, as a result of the stimulus offered, the third element, proper action,

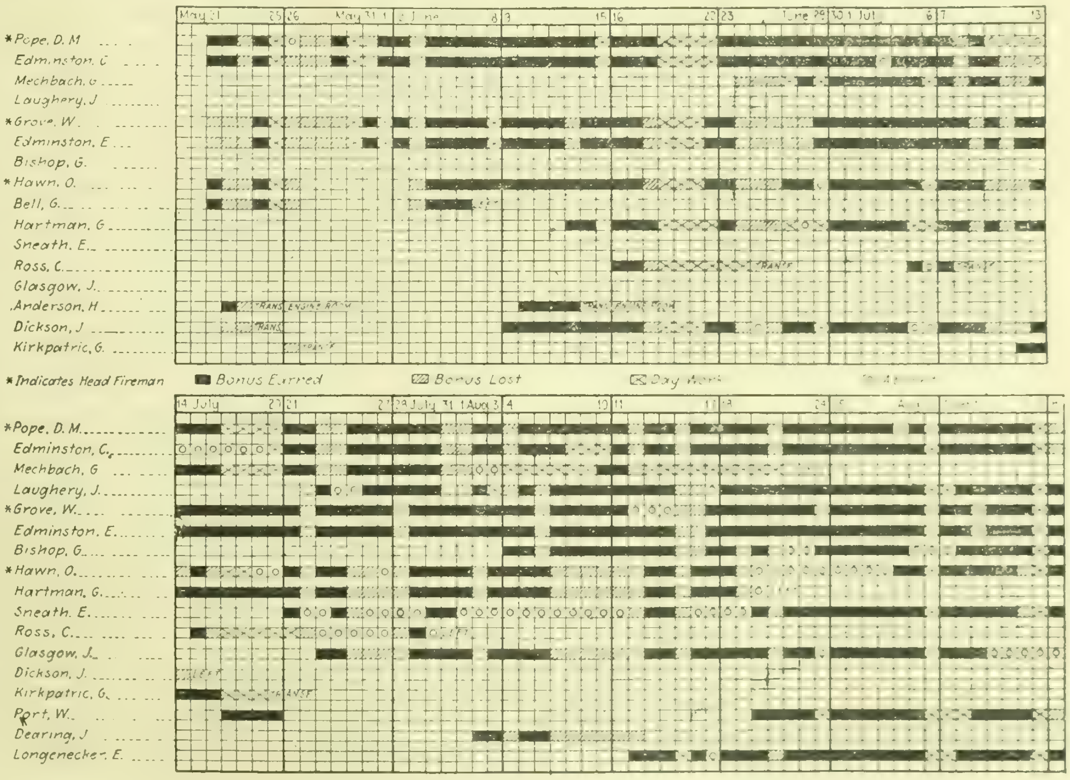


FIG. 7.—FORM OF GRAPHICAL BONUS RECORD IN USE.

is yet far from being secured. To act in the chosen direction one must know how the desired result is to be accomplished. Lack of sufficient information necessarily produces a strong perception of uncertainty coincident with suffering. After the excellent essay on training workmen by Mr. H. L. Gantt, little if anything can be said on this subject except that, in case of firemen, the success of attainment of the task is determined by detailed, patient, and prolonged training and instructions, and as such this is the most important function of the management. A dummy furnace was found to be an excellent means to break in the green hands.

Although the above requirements of additional compensation and exhaustive training for stimulating men's will to co-operate with the management in attainment of the state of high efficiency are imperative, they alone are insufficient. The psychical conditions under which the men have to work must be so arranged as to ensure the fullest preservation of their strength, health, and psychical faculties. In a boiler house the amount of work per man per hour is constant, and cannot be increased without knocking down the efficiency to a ridiculously low figure, but the number of foot-pounds of work can be reduced in an inverse proportion to the increase of efficiency, so that the question of preservation of a man's health, &c., eliminates any consideration of overspeeding. The conditions which then remain for consideration are (*a*) temperature of room; (*b*) ventilation (dust and draught); (*c*) lighting; (*d*) drinking water; (*e*) restful seats; and (*f*) sanitary washrooms.

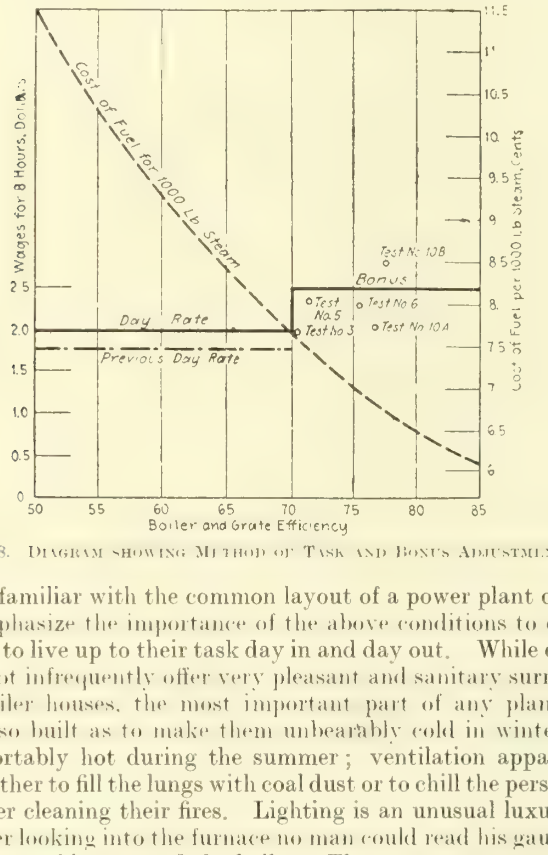


FIG. 8. DIAGRAM SHOWING METHOD OF TASK AND BONUS ADJUSTMENT.

One familiar with the common layout of a power plant cannot over-emphasize the importance of the above conditions to enable the men to live up to their task day in and day out. While engine rooms not infrequently offer very pleasant and sanitary surroundings, boiler houses, the most important part of any plant, are usually so built as to make them unbearably cold in winter and uncomfortably hot during the summer; ventilation apparently serves either to fill the lungs with coal dust or to chill the perspiring men after cleaning their fires. Lighting is an unusual luxury, so that after looking into the furnace no man could read his gauges or examine anything around the boiler. The petty annoyances and feelings of discomfort divert the attention of the men from the performance of their duty to means of avoiding the annoyance or harm. Steady attention on the part of the fireman is much more important than is generally realised. A psychological test conducted by the writer on the effect of the occasional drop of attention with the same individual and with individuals possessing different degrees of this faculty proved that physical condition and strength being constant, the boiler efficiency percentage is in an almost direct proportion to the degree of attentiveness of the fireman.

With healthy, sanitary, and pleasant surroundings as a sufficient criterion for judging whether the man's task is harmful, a simple and apparently reliable method was devised by the writer. It is evidently beyond the means of ordinary time study to define whether or not the possible output in a unit of time is a safe one from the viewpoint of the preservation of the individual and the nation. The problem in itself is twofold: (*a*) strain per unit of time in foot-pound per square inch of cross-section of a muscle, and (*b*) number of time units at work. As in every case where more than two variables are evolved the maxima are determined by the limiting conditions of variables, and the constant safe limit can be reached either by a comparatively great strain during a

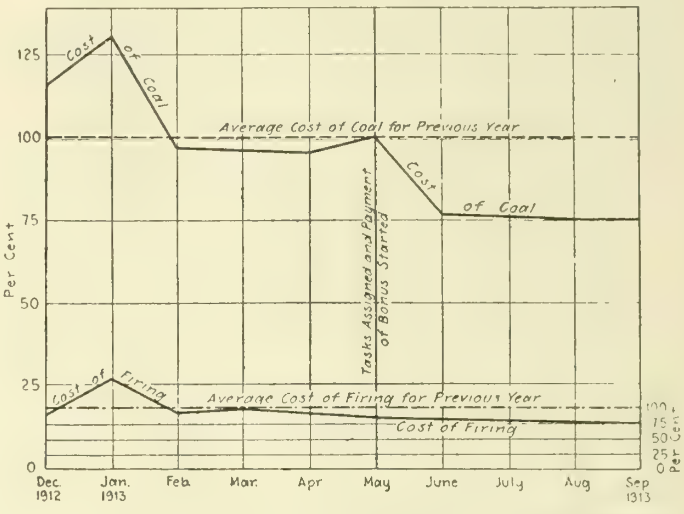


FIG. 9.—GRAPHICAL RECORD OF ACTUAL REDUCTION OF COST OF COAL AND LABOUR PER KILOWATT-HOUR.

short time or a less intense strain during a longer period. If t and s are time and strain respectively, the equation

$$\frac{d}{d}\left(\frac{ct}{t} \cdot \frac{s}{c's}\right) - 1,$$

if differentiated, illustrates the problem; yet, whether factor c for time or c' for strain has the same numerical value the experiments alone are able to show. More study along this line is needed. In our experience we adopted in addition to time studies, a careful investigation of fatigue, both mental and physical, and measurements of the vitality of the men affected by various conditions of work and number of working hours per day. No task is reasonable unless the workman can fully regain his loss between quitting time and recommencing work the next day, and during a sufficiently long period of observation a man should be able to gain or at least not lose anything in his vitality. Observations should cover at least four factors: (*a*) Weight of body; (*b*) blood pressure; (*c*) temperature of body; and (*d*) pulse. The blood analysis while considered desirable is too cumbersome to make, and other indications being favourable can safely be omitted. Almost unanimous statements of those observing the task work performed in a great variety of industries assert that men are gaining in health and spirit, but scientifically definite data alone could prove this fact beyond any doubt.

DAILY POWER PLANT REPORT

PENN CENTRAL LIGHT AND POWER CO.
STATION *Warrior Ridge* FOR 24 HOURS ENDING 9 (MONTH) 14 (DAY) '13 (YEAR) 7 A.M. (HOUR)

BOILER ROOM	WATCH 1	WATCH 2	WATCH 3	ENGINE ROOM	WATCH A	WATCH B	WATCH C
COAL USED (BANKING INCLUDED)	48800	49200	34000	HYDRO ELECTRIC OUTPUT	980	850	30
WATER EVAPORATED	419800	408200	284000	STEAM GENERATED OUTPUT	21220	20450	15000
ACTUAL EVAPORATION	8.62	8.32	8.37	LOAD FACTOR	79.5	64.4	67.5
FACTOR OF EVAPORATION	1.2187	1.2185	1.2287	STEAM PER KWH	19.78	20.00	18.85
EQUIVALENT EVAPORATION	10.50	10.13	10.28	COAL PER KWH	2.30	2.40	2.26
EFFICIENCY OF GENERATION	73.4 %	70.8 %	71.8 %	THERMAL EFF-CY OF PLANT	10.71	10.27	10.73
COST OF FUEL PER 1000 LBS OF STEAM	0.0815	0.0845	0.0833	COST OF FUEL PER KWH (INCLUDING BANKING)	0.00201	0.00204	0.00200

REMARKS

COAL USED FOR BANKING 1 BOILERS DURING 6/9 HRS. 55/30 MIN. 3000 LBS COAL ANALYSIS BTU AVE B.T.U 13900

TOTAL OUTPUT ______ KW HRS ______ S. D. Port SIGNED

FIG. 10.—EXAMPLE OF DAILY REPORT FROM THE PLANT SHOWING AVERAGE RESULTS.

Finally, the time element in relation to task setting for men, particularly if the work requires a considerable strain, must be settled by examination no less careful than the study of the time rate of driving boilers. When, however, as in the case of firemen, both physical strain and attention are required, it was found that with strong, healthy individuals the limiting factor on number of

hours of profitable work is set not by physical exhaustion but by weariness of spirit. Other conditions being equal, a fireman on a 12-hour watch is found to be about 4·5 per cent. less efficient than the same man on an 8-hour shift.

This time-limiting factor on human efficiency, taken in conjunction with a scientific certainty in determination of the most advantageous thermal efficiency, formed the grounds on which the writer rejected the sliding scale of bonus rate results exceeding the task set by various degrees. The task set must be so little below the most advantageous point that it could be reached with greatest benefit to all concerned and it is not desirable from economical aspects either to fall short of or considerably to overreach it. Offering extra compensation for excess of the task requirement means in final analysis either that the investigator did not determine both limits, or that the management tempts a man to do more than the average employer dares to ask directly.

The example of efficient co-operation between employer and employé in the power plants of public utility corporations here referred to demonstrated the value of the above principles for setting task and accomplishing the predetermined results in firing boilers. The diagram in Fig. 9, showing cost per kilowatt-hour of fuel relative to firemen's pay-roll and bonus before and after adoption of scientific basis for firing, presents, outside of the interesting reduction in cost since the change of method took place, another feature also of no less importance, namely, that since that time the unit cost remained practically constant, while previously it fluctuated considerably. A sample of daily power plant report is shown in Fig. 10.

The writer does not claim to have made any new discovery or exhaustive treatment of the technique of the question. The undertaking of presenting to the profession a brief outline of systematic method of task setting for one particular job can be considered fairly fulfilled, if the necessity of thorough scientific research and accumulation of available data for further enlightenment of the many still obscure facts and their co-ordinations is sufficiently demonstrated.

CORRESPONDENCE.

Marine Gas Plants.

To the Editor of "The Mechanical Engineer."

Dear Sir,—

In your report of Prof. W. H. Watkinson's lecture at Liverpool University on the subject of "Recent developments in Marine Propulsion," the reference to the position of marine gas plants is of special interest. The Professor states that very few men are devoting themselves to the solution of the marine gas producer problem. With this I agree, and although the utility and desirability of this new venture may be duly recognised, the writer reiterates that we on this side are too much inclined to the "ca canny" policy. Things are moving somewhat faster in U.S.A. in this department. But the problem is seldom tackled in the broadminded way which it deserves. So far as at present revealed it appears to be an indisputable fact that the marine gas engine is a long way ahead of gas producer development, and that the former is practically held up from successful application. In case too much should be made out of the appearance of remissness on the part of gas producer engineers, the writer takes this occasion to express his view and knowledge of the gas producer position. Hitherto attention has been directed to the problem of constructing gas producers adaptable to marine conditions but using anthracite coal or coke. That is a comparatively simple problem, but it has always seemed not worth solving. For what besides the saving of space is the advantage of reducing the quantity of fuel used for propulsion if its cost is raised? It has for years been the special study of the writer to consider the construction of a marine gas producer, conjointly with the use of cheap bituminous fuel. In other words, substitute bituminous fuel for anthracite, and thus create an outstanding claim for all round economy. This can only be accomplished by the satisfactory application of two elementary conditions, viz., continuity of operation and complete tar elimination. For marine conditions also it is essential that complete tar elimination be by conversion of all volatile products into fixed gases within the generator, and thus end the necessity for outside series cleaning plant. The writer has not confined himself to a contemplation of the problem as thus stated, but has done much towards solving the problem on the above lines by reducing it to practice. It will, however, be readily granted that to properly grapple the marine problem on a good practical scale it should not be left to the enterprise of private individuals. The problem is a fairly big one, but it is averred that its practical solution is within measurable distance, and that it is a commercial proposition worthy of the attention of the capitalist as well as of the engineer. In the *Mechanical Engineer* of October 7th, 1910, you described and illustrated one invention which reveals a new feature in gas producer construction involving the chemistry of gas manufacture, and designed primarily for the elimination of all tarry matters by their conversion into fixed gases within the generator. That design was not intended to be more than a practical embodiment of a new principle. Since then, however, much has been accomplished, and as now constructed simplicity and efficiency are secured. By minor modifications of structure marine conditions can be met and the future of gas ship propulsion definitely advanced to a position of prime importance by the satisfactory gasification of bituminous coal. When this is done it will do much to stave off any abnormal demand for oil and relegate it to its proper and economical field of usefulness.

Yours, &c.,

John Stewart.

219, St. Vincent Street,
Glasgow,
Dec. 22nd, 1913.

INDUSTRIAL AND TRADE NOTES.

T. Sugden, Ltd.—The directors of this company have declared a dividend at the rate of 15 per cent. per annum, the same as last year.

Clyde Shipbuilding Record.—The Clyde shipbuilding returns for the year have now been made up, and, as anticipated, the figures created a new year's record. The total amounts to 767,000 tons, which exceeds last year's record total by over 120,000 tons.

Tyne Shipbuilding Record.—The Tyne shipbuilding returns for the year show that 100 vessels aggregating 341,826 tons were launched, an increase of seven vessels and 11,035 tons on last year, and a decrease of 23 vessels, but an increase of 5,360 tons on the record year 1911. The output for the past year, therefore, constitutes a new record.

Magnetic Lift Crane Fitted with Turbo-Generator.—The Brown Hoisting Machinery Company, of Cleveland, Ohio, have recently been experimenting with a 15-ton locomotive crane with an electro-magnet lift fitted with a 5 kw. Terry turbo-generator set. By this means electric wiring exterior to the locomotive is eliminated. The turbo-generator set is independent of the other operating portions of the mechanism. The crane has a 40ft. boom.

Census of Motor-vehicles.—In a recent issue of "The Car," there is a motor census indicating that there are now 425,000 motor vehicles in use in this country, 227,000 of which are motor cars, 179,000 motor cycles, and the balance heavy motor vehicles. It is estimated that 43,000 cars have been acquired during the year under review, as well as 38,000 motor cycles and over 5,000 heavy motor vehicles.

Types of Motors in Demand in Egypt.—There is, says a recent German Consular report, a considerable demand in Egypt for small gas and oil motors, small electric motors for works, such as printing works, pumping, &c., dynamos for lighting purposes and large motors for cotton spinning works and large pumping plants. Great Britain is the leading supplier of electric, gas, and petrol motors, but there is keen competition from Switzerland. German competition in these lines is of comparatively recent date. In other machinery the United States is the chief supplying country.

Gas Engines in Japan.—According to an Austrian Consular report, there is a profitable business to be done in gas engines in Japan. In motors up to 25 h.p., the Japanese machinery industry is able to supply the demand, and in consequence of the high rates of import duty to shut out foreign competition. In medium sizes, from 25 h.p. to 50 h.p., there is a keener competition between the home industry and foreign productions. In motors over 50 h.p. foreign trade is predominant. In the year 1912 the imports of gas motors amounted to about £140,000, and came chiefly from Germany, Sweden, United States, and France.

Japanese Coal Trade.— The Japanese coal trade (writes the Nagasaki correspondent of the Press Association) has been active throughout the present year, the demand from all quarters at home and abroad showing a steady tendency to increase faster than the output. The production of coal in Japan and the Japanese collieries in South Manchuria is expected to aggregate 20,000,000 tons next year. The quantity exported during the first six months of 1913 was 2,000,000 tons, and it is believed that the total for the year will reach 4,000,000 tons, whereas in 1912 it was only 3,000,000 tons. Strenuous efforts have been made by the colliery owners to increase the output, but only the opening of new fields can make any material difference.

Light Railway. The Board of Trade have recently confirmed the undermentioned Order made by the Light Railway Commissioners: London and North Western Railway (Wolverhampton and Cannock Chase Light Railway) Transfer and Amendment Order, 1913, authorising the transfer to the London and North Western Railway Company of the powers, &c., conferred on the Wolverhampton and Cannock Chase Railway Company by the Wolverhampton and Cannock Chase Railway Acts of 1901 and of 1903, and by the Wolverhampton and Cannock Chase Railway (Light Railway) Orders of 1907 and of 1910, and extending the time limited for the completion of part of the railways thereby authorised, and authorising the London and North Western Railway Company to abandon other parts of such railways, and to construct new light railways in substitution therefor, and for other purposes.

Midland Railway Statistics.—Some interesting figures concerning the Midland Railway have recently been published by the Midland Railway Temperance Union, Derby. According to these, the total number of employés is 70,901. Of this number 29,800 represent the uniform staff, 2,547 the clerical staff at Derby, and 13,659 total number of workmen in all shops. The annual salaries and wages paid by the company amount to £5,208,836. Of engines there are 3,024, carriage stock 6,146, wagon stock 130,741, horses 5,365, road vehicles 7,123. During the 12 months, 44,781,246 passengers were carried. There are 228,471 season ticket holders, and the train mileage was 45,804,941. In the 12 months 1,919,273 tons of coal and coke were burnt, and the cost of coal consumption works out at £2,760 per day. The company's stations number 603. The capital already expended on this particular railway aggregates £128,825,656. It owns 1,761 miles of line, and 13 miles are either in course of construction or have been authorised, while it partly owns 329 miles.

A Large Electric Hoist. —A contract for the largest electric hoist in America was, according to "Engineering News," recently awarded by the North Butte Mining Company to the Westinghouse Electric and Manufacturing Company. The hoisting drum, which will be 12ft. diam., will be driven by a direct current motor of the type used in steel mills, running at a speed of about 71 revs. per minute. This motor will take power from a motor-generator set equipped with a 15-ton flywheel for the elimination of peaks in the power line during starting and acceleration. The electrical equipment alone will weigh more than 250 tons. The hoist motor will have a maximum intermittent rating of 4,500 h.p., and the motor-generator set will be driven by an induction motor having a continuous normal rating of 1,400 h.p. The difference between these ratings, of course, represents approximately the amount of energy that will be supplied by the flywheel during starting. Round rope 1¾in. diam. will be used, and the equipment is designed for a normal rope speed of 2,700ft. per minute, with a maximum of 3,000ft. per minute. The capacity of the hoist will permit 300 tons per hour being hoisted from a 2,000ft. level, or 200 tons per hour from a 4,000ft. level. The ore will be handled by means of skips, having a capacity of 7 tons each. Hoisting will be accomplished in balance, but the equipment is large enough to take care of unbalanced hoisting. A number of special safety devices are included in the equipment, *e.g.*, electrically released brakes, automatic slow-down devices to prevent the skip or cage from going through the head sheaves, and a special controller to limit the speed when men are being hoisted.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1912.

Internal-combustion engines. Smith. 20762.
Heating of fluids. McCourt, and Radiant Heating, Ltd. 22305.
Construction of turbine rotors. Parsons, Carnegie, and Cook. 23049.
Controlling steam engines. Esplen. 25271.
Apparatus for cleaning iron and steel. Macnicol. 27521.
Purification or extraction of iron. Benjamin. 27968.
Universal joints applicable for shafts. Maddick. 28067.
Pneumatic stamps for crushing ore. Holman & Holman. 28116.
Variable speed gears. Collier & Collier. 28215.
Steam generators. Williams. 28218.
Valves for internal combustion engines. Allgemeine Elektricitäts Ges. 28226.
Steam boilers. Pollak. 28236.
Foundry moulding boxes. Rix, Moore, Stoddart, and Paton. 28325.
Preventing incrustation in steam generators. Coke Oven Machinery Co. 28395.
Hack saw machines. Wicksteed. 28414.
Self locking nuts. Frankiess. 28592.
Measurement of the flow of gas in pipes. Edmunds. 28659.
Gauge for indicating efficiency of condensers. Scanes. 28753.
Gas producers. Franks & Sanders. 28936.
Internal-combustion engine valves. Knight. 28990.
Turbine rotors. Hutson & Ford. 29075.
Machines for testing lubricants. Hislop. 29086.
Change speed friction gearing. Burgess. 29771.
Starting motors for engines. Rushmore. 29932.

1913.

Steam and vacuum traps. Ogden. 1322.
Internal combustion engines. Constantinesco. 1683.
Gas producers. Home. 1783.
Furnaces for roasting ores. De Spirlet. 1849.
Bearings for lathe centres. Sokal. 3047.
Pumping systems. Rosencrans. 3453.
Internal combustion engines. Fraser, Brimmer, and Murphy. 4051.
Carburetters for internal combustion engines. De Veulle. 5100.
Hydraulic pumps. Mistral & Broche. 5624.
Float chambers for carburetters. Hans. 5631.
Chain belts for the transmission of power. Brooks & Holt. 6201.
Internal combustion engines. Gardner. 6238.
Furnaces for pulverous fuel. Von Porat. 6639.
Governing mechanism for elastic fluid turbines. Warwick Machinery Company. 7897.
Two stroke cycle internal combustion engines. Kemp. 7926.
Tool holders for tool grinding machines. Lumsden. 8667.
Steam superheaters. Litton. 8702.
Lathes. Wilhelm Hegenscheilt Ges. 9569.
Internal combustion engines. Graham. 9925.
Carburetters for internal combustion engines. Claudel. 11239.
Tool socket or chuck. Archer. 11292.
Fuel pumps for internal combustion engines. Miller. 12247.
Synchronising devices for facilitating the coupling of rotating shafts. Yarrow. 13080.
High speed air compressor. Lang. 13129.
Anti friction bearings. Mellersh-Jackson. 13449.
Multi cylinder internal-combustion engine with at least one charging pump. Allgemeine Elektricitäts Ges. 13914.
Mechanical stokers. De Grahl. 15042.
Carburetters. Smith. 15197.
High speed circular saws. Hendee. 15476.
Exhaust silencer for internal-combustion engines. Tobey. 15487.
Distribution valve for internal-combustion motors. Evans. 15841.
Change-speed gear. Marks. 16687.
Centrifugal compressors. Mellersh-Jackson. 17431.
Tube cleaners. Rudolph. 21836.
Adjustable boring tools. Blocksom. 22597.
Construction of gear wheel. Parsons, Carnegie, and Cook. 23703
Driving belts. Wright. 25218.

METAL QUOTATIONS.

TUESDAY, DECEMBER 30TH.

Aluminium ingot	96/- per cwt.
,, wire, according to sizes, &c. ......from	121/- ,,
,, sheets ,, ,, ... ,,	126/- ,,
Antimony £28/-/-	to £30/-/- per ton.
Brass, rolled	7½d. per lb.
,, tubes (brazed)	9½d. ,,
,, ,, (solid drawn)	8¼d. ,,
,, ,, wire	7⅝d. ,,
Copper, Standard	£66/2/6 per ton.
Iron, Cleveland	50/6 ,,
,, Scotch	56/6 ,,
Lead, English	£18/5/- ,,
,, Foreign (soft)	£17/15/- ,,
Mica (in original cases), small	6d. to 3/- per lb.
,, ,, ,, medium	3/6 to 6/- ,,
,, ,, ,, large	7/6 to 11/- ,,
Quicksilver	£7/10/- per bottle.
Silver	26⅝d. per oz.
Spelter	£21/15/- per ton.
Tin, block	£170/15/- ,,
Tin plates	12/9 ,,
Zinc sheets (Silesian)	£25/-/- ,,
,, (Stettin; Vieille Montagne)	£24/12/6 ,,

The Mechanical Engineer.
An Illustrated Weekly Journal
Vol. 33, No. 833.

Edited by
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Telegrams: "Scientific," Manchester.
Telephone No. 6055 City.

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Advertisements, displayed, for insertion in current issue should reach our Manchester office not later than first post Tuesday morning, and small prepaid advertisements not later than first post Wednesday morning.

Foundry Experience and Workshop Management.

MR. ROBERTS' paper on pattern making, recently read before the Manchester Association of Engineers, contained not only some practical observations on pattern-shop equipment, but also some thoughtful remarks on the value of harmonious working between the various departments of an engineering shop in securing efficiency. While this seems a truism and is the principal aim of all good management, it is surprising how often this essential to economical production is wanting. This is due partly to the natural conservatism that clings more or less round every skilled trade and leads it to decline instruction from another, *e.g.*, the moulder does not want the pattern-maker to teach him his business, and vice versâ, while both hold the contemptuous opinion that those in the drawing office are not fit to give instructions to either of them. But more, we think, is due to the lack of foundry experience on the part of managers in general. How many of those who hold such a position would be capable of carrying through even a comparatively simple piece of work on the foundry floor? Very few, and fewer still would know how to tackle a fairly difficult job. The fact is, the foundry is regarded as a very dirty place, which it no doubt is, and its handicraft skill as very inferior to that, say, of the pattern-maker or the fitter, which it certainly is not, and generally as a department of which the aspiring engineer apprentice with his eye on eventual managership need take little cognisance. This is a mistake, for the ignorance of this department is responsible for more expense in pattern shop and foundry than many works managers are aware of. It is of course impossible to lay down rules as to the training essential, or desirable, for a works manager. So much depends on circumstances, the nature of the work done, simple or complicated, heavy or light, &c., but we venture to assert that in a shop engaged on heavy and varied work and including a foundry in its equipment a technical acquaintance with its work

would stand the manager in quite as good stead as a similar acquaintance with the machining and fitting shops. These departments can certainly be better left to take care of themselves under their respective foremen without risk of serious increase in labour cost on any particular job, than can the foundry, which, owing to technical ignorance on the part of the management, it often has to do. We commend this view, as the outcome of intimate practical knowledge, to the attention of all engineering students who, in connection with their shop training, have an opportunity of choosing the disposition of their time amongst various departments. The pattern shop and the foundry are both too much neglected for the fitting bench and the erecting shop, although in the two former mistakes are more easily made and more costly to rectify.

In the course of his paper, Mr. Roberts gave a few illustrative examples of the extent to which harmony of working between moulder and pattern-maker was conducive to economy of output, and how much more frequently the perception by the former of the practical difficulties of the latter could be advantageously applied. How often, for instance, is the work of the moulder increased through the sparing allowances of taper afforded and the rigid adherence of the drawing office to right-angle sections for box beds, &c., when they might be made just as easily, be designed with a rake that would enable the pattern to "jump" out of the sand without having to knock it to pieces or shake the mould in a way that calls for no end of time in patching up. How often again does the moulder familiar with the resources of his craft find the expense of costly patterns incurred for moulds that might with little modification be as easily made with a strickle, or, in other cases, ugly bits pinned on to patterns that involve a troublesome "draw back" in the mould that materially increases its cost and at the same time, owing to the complication involved, enhances the risk of a "waster." He could probably point this out if he knew something of other departments and had a better general knowledge of the purpose the casting was intended to serve, but in these respects he is usually sadly lacking, and concludes that the "tag-piece" on the pattern is an unfortunate necessity from the moulding point of view and permits of no other alternative, shrugs his shoulders and makes the best of it. In other cases the foundry, with a false idea of economy, is given old patterns to use which are so battered that to make a few castings call for the expenditure of so much time on each mould that it would be far cheaper to provide a new pattern to begin with. Here again a manager with technical knowledge of the foundry would avoid this penny wise and pound foolish policy. The influence of this knowledge would be perceptible on the job in the drawing office to begin with, and find an economical reflection in every other department through which it subsequently had to pass.

Manchester University Special Engineering Lectures.—A special short course of five lectures will be delivered as follows: (1) "Design of Steam Turbines," by Gerald Stoney, B.E., F.R.S., M.Inst.C.E., on January 22nd and January 29th; (2) "Coast Erosion and Coast Protection," by Ernest R. Matthews, A.M.Inst.C.E., F.R.S.E., on February 5th and February 12th; (3) "The New Principles involved in the Humphrey Pump," by H. A. Humphrey, M.Inst.C.E., on February 26th. Lectures 4 and 5. The lectures will be held in the Engineering Department, Coupland Street. A fee of one guinea will be charged for the five lectures. Members of the Manchester Association of Engineers may obtain tickets at half-a-guinea on application to the registrar.

BOOK REVIEWS.

The Journal of the Institute of Metals. (Vol. X.) Edited by G. Shaw Scott, M.Sc. The Institute of Metals. London: Caxton House, Westminster, S.W. 477 pp. Price 21s. net.

The tenth volume of Proceedings just published by the Institute more than maintains the previous standard of excellence. The most important paper in this volume is the Second Report to the Corrosion Committee, together with the discussion and communications thereon. Besides this there are 10 other papers embodied in the volume, including: (1) "A Study of Volume Changes in Alloys," by Mr. J. H. Chamberlain, M.Sc.; (2) "The Micro-Chemistry of Corrosion: I. Some Copper-zinc Alloys," by Dr. C. H. Desch and Mr. S. Whyte, B.Sc.; (3) "Metallographical Researches on Egyptian Metal Antiquities," by Mr. H. Garland; (4) "The Specific Volume and Constitution of Alloys," by Dr. W. M. Guertler; (5) "The Copper Rich Kalchoids," by Prof. S. L. Hoyt; (6) "A Method of Improving the Quality of Arsenical Copper," by Mr. F. Johnson, M.Sc.; (7) "The Influence of Phosphorus on Some Copper-aluminium Alloys," by Prof. A. Read, M.Met.; (8) "The Annealing of Gold," by Dr. T. K. Rose, Assoc.R.S.M.; (9) "The Intercrystalline Cohesion of Metals—Second Paper," by Dr. W. Rosenhain, F.R.S., and Mr. D. Ewen, M.Sc.; (10) "The Determination of Oxygen in Copper and Brass," by Mr. T. West, M.Sc. The section of the journal devoted to abstracts of papers relating to the non-ferrous metals and the industries connected therewith, is another useful feature.

* * *

Water: Its Purification and Use in the Industries. By William W. Christie, Mem. Am. Soc. of Engineers. London: Constable & Co. 8in. by 5½in. 219 pp. Price 8s. 6d. net.

This is an interesting monologue on the subject of water softening, but its value to British readers is marred by the fact that it relates mainly to American practice. The subject is now well understood, and the varieties of apparatus are differentiated from each other mainly by details of construction. These are indicated by the photo illustrations with which the book is furnished, but as the several kinds of apparatus are only designated by various alphabetical letters these do not afford much help to the reader who desires to select one to meet his special requirements. It would, we think, be an advantage if some key to this list had been given so that the various makes could have been identified.

BOOKS RECEIVED.

Soft Soldering and Hard Brazing. A practical treatise for the metal worker. By James F. Hobart, M.E. London: Constable & Co. 7in. by 4¾in. 190 pp. 4s. net.

Examinations in Science and Technology, 1913. List of Candidates who passed in 1913. Wyman & Sons, Ltd., Fetter Lane, E.C. Price 9d.

Village Electrical Installations. By W. T. Wardle, A.M.I.E.E. London: Whittaker & Co. 80 pp. 2s. net.

Elementary Graphic Statics. By John T. Wight, A.M.I.M.E., with 135 illustrations. London: Whittaker & Co.

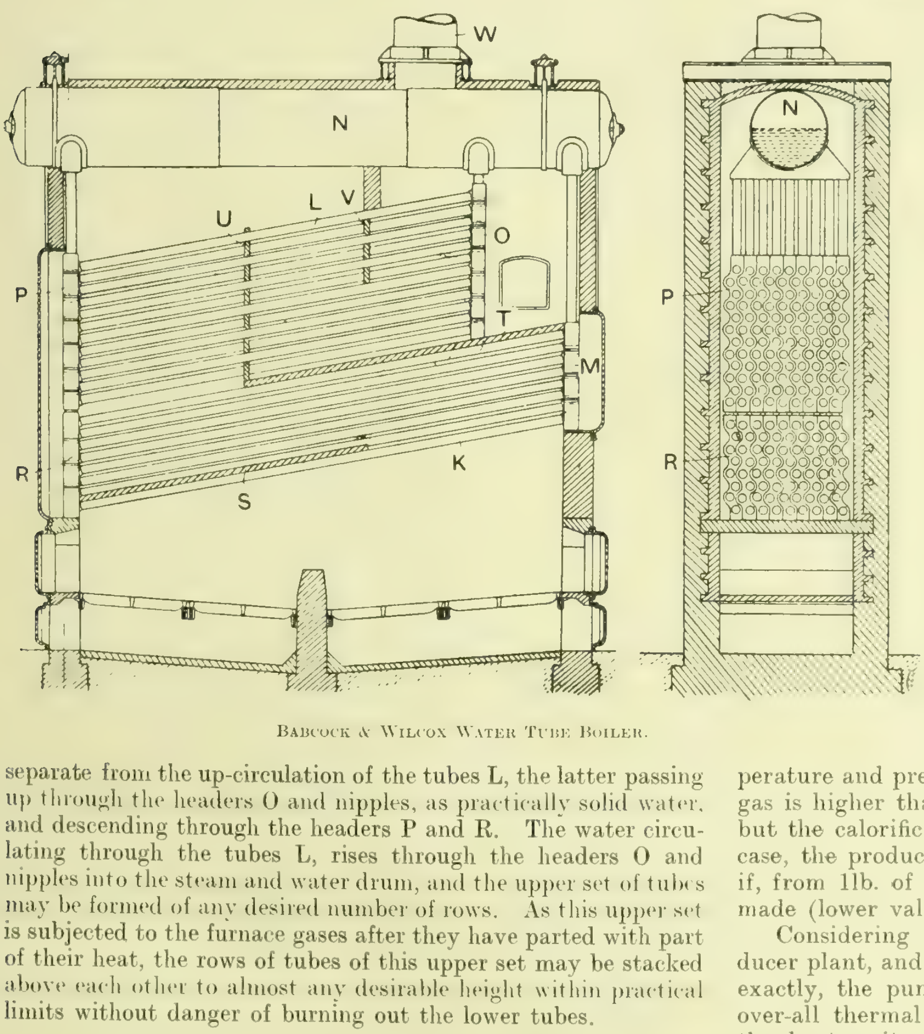
BABCOCK & WILCOX WATER TUBE BOILER.

The Babcock & Wilcox Company, of New York, have recently patented the arrangement of water tube boiler shown in the accompanying sectional views. It comprises a lower set of inclined tubes K and an upper set of inclined tubes L. The lower tubes are connected at one end to vertically extending headers M, of the ordinary zig-zag or serpentine type, and the upper ends of these headers are connected by pipes or nipples to a steam and water drum N. The upper set of tubes L is shorter than the lower set and at one end they are connected to vertical headers O, which are connected by nipples to the steam and water drum. The opposite ends of the tubes L are connected to vertical headers P, having at their upper ends nipples connecting to the steam and water drum. The headers P extend downwardly far enough to receive all of the tubes L and are nippled at their lower ends to a

lower corresponding set of headers R receiving the ends of the lower set of water tubes K.

Two sets of grates extend from the front and rear walls, to a bridge wall, extending transversely at an intermediate point. Firedoors are provided at both ends of the setting. As shown, a lower horizontally-extending baffling S lies on the lower row of water tubes and another horizontal baffle T extends from the opposite end and lying on the upper row of the lower set of tubes K. At the end of the baffle T is a vertical baffle U, leaving a gas port at its upper end, and a depending baffle V is placed between the baffle U and the up-take W. The flames and gases are thus given a tortuous course along and across the water tubes. The space between the headers O for the upper set of tubes L and the pipe connections for the corresponding headers of the lower set of tubes is large enough to allow entrance of a man through the side wall of the setting. For this purpose doors are provided in the side walls.

In the operation of the boiler, the water and steam in the lower tubes flow into the headers M, and then through the pipe connections directly into the steam and water drum, where the steam is released. A rapid circulation may thus be provided in the lower set of tubes which is nearest the furnace and is most liable to be burnt out. This up-circulation of steam and water passes upwardly



Babcock & Wilcox Water Tube Boiler.

separate from the up-circulation of the tubes L, the latter passing up through the headers O and nipples, as practically solid water, and descending through the headers P and R. The water circulating through the tubes L, rises through the headers O and nipples into the steam and water drum, and the upper set of tubes may be formed of any desired number of rows. As this upper set is subjected to the furnace gases after they have parted with part of their heat, the rows of tubes of this upper set may be stacked above each other to almost any desirable height within practical limits without danger of burning out the lower tubes.

The Institution of Civil Engineers: Students' Meetings. At the students' meeting, held at the Institution on Friday, December 19th, Mr. W. E. Gurry, Stud. Inst. C.E., read a paper entitled "Air Filtration and the Cooling and Ventilating of Electrical Machines." The chair was taken by Mr. J. S. Highfield, M.Inst.C.E. The author dealt with the general principles of, and the plant used for, air filtration and the cooling and ventilating of electrical generators. The paper was illustrated by a number of lantern slides. An interesting discussion followed, the proceedings terminating with a vote of thanks to the chairman.

TEST OF HUMPHREY PUMPING PLANT AT CHINGFORD.

An interesting report has recently been issued on the test of the Humphrey pumping plant installed at King George V Reservoirs, Chingford, Middlesex. The tests were made under the supervision of Mr. William B. Bryan, M.Inst.C.E., Chief Engineer of the Metropolitan Water Board. The pumping plant, which was supplied by the Pump and Power Company, Ltd., 38, Victoria Street, Westminster, S.W., to the order of the Metropolitan Water Board, consists of five Humphrey internal combustion pumps, working on producer gas, the gas being supplied by four Dowson pressure producers gasifying anthracite coal. The pumps were designed by the Pump and Power Company, and constructed by Siemens Bros.' Dynamo Works, Ltd., Stafford. The producer plant was constructed by the Dowson and Mason Gas Plant Company, Ltd., Levenshulme, Manchester.

Four of the pumps were each to be capable of delivering 40,000,000 gallons of water per day of 24 hours, or 27,780 gallons per minute, and the remaining pump to be capable of delivering 20,000,000 gallons per day of 24 hours, or 13,890 gallons per minute, the water being raised in all cases to a height of from 25ft. to 30ft. The pumps are of the "drowned suction four-stroke cycle" type. Three of the Dowson producers were each to be capable of gasifying 370lbs. of anthracite per hour, and the remaining producer to be capable of gasifying 138lbs. per hour. The pumping plant is installed for the purpose of raising water from the River Lea into the large storage reservoir at Chingford, Essex. Fig. 1 is a diagram showing the arrangement of the pumps, producers, waterways, &c.

Fuel Guarantees.—The contract required that the fuel consumption for each pump should not exceed 1·1lbs. of anthracite gasified in the producers per actual water horse-power hour when working at full load during an official trial of six hours. (The expression "actual water horse-power hour" means the work done in raising the actual quantity of water pumped, the lift being measured as between the average suction level in the pump pit and the average water level in the delivery tower.)

The manufacturers of the producer plant guaranteed their producers to generate 78 cub. ft. of gas, having a calorific value (lower scale) of 150 B.T.U. per cubic foot, from 1lb. of suitable anthracite coal. The quantity of producer gas made naturally depends upon the prevailing temperature and pressure; for instance, if the temperature of the gas is higher than normal the volume of gas will be greater, but the calorific value per unit volume will be less. In any case, the producer efficiency guarantee would not be fulfilled if, from 1lb. of coal gasified the total heat units in the gas made (lower value) should be less than $150 \times 78 = 11{,}700$.

Considering the pumps themselves apart from the producer plant, and assuming the latter to perform the guarantee exactly, the pumps, to fulfil their guarantee, must have an over-all thermal efficiency of 19·7 per cent. calculated from the heat units supplied in the gas and the work done in water raised.

Method of Carrying Out Tests.—The methods adopted were agreed as between Mr. W. B. Bryan, M.Inst.C.E., Chief Engineer of the Water Board, and Mr. H. A. Humphrey, M.Inst.C.E., on behalf of the Pump and Power Company, Ltd. It was decided to carry out the producer tests independently of the pump tests, that is to say, a six-hour test on each of the producer units was first made in order to ascertain for each producer the quantity and heat value of the gas made per 1lb. of anthracite used. A six-hour test on each pump was then carried out to ascertain the amount of gas consumed, and the total heat value of the gas per actual water horse-power hour. Combining the results of the pump

tests with the average result obtained from the producer tests, the coal consumption per actual water horse-power hour was determined.

Producer Tests.—Each producer was tested for a period of six hours. The height of the fire was measured at the beginning of the test, and maintained approximately constant, and in all cases the level at the end of the test was the same as at the beginning. Coal was fed into the producer about every 15 minutes, and the gas made was measured through a gas meter and was burnt. The meter was of the rotary type, and was calibrated before and after each test against the fall of a gas holder. By regulating the valve 1 shown on Fig. 1, the outflow of gas was controlled until the gas holder 2 remained approximately stationary, when the

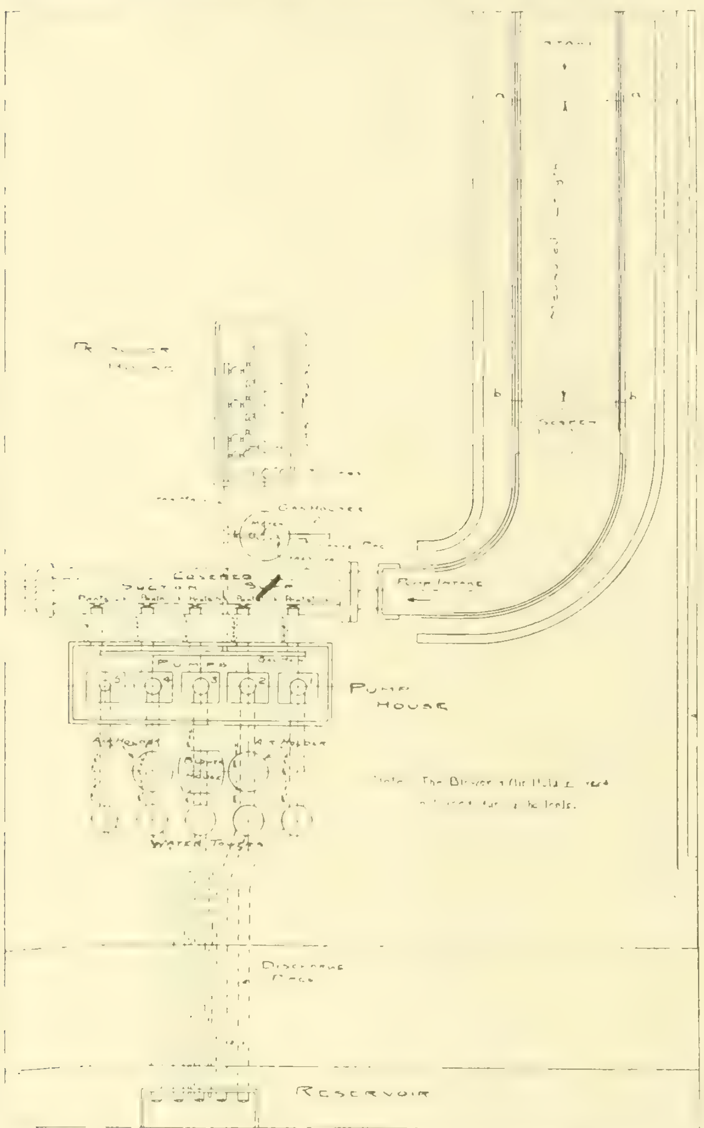


FIG. 1. GENERAL ARRANGEMENT OF HUMPHREY PUMPING PLANT AT CHINGFORD RESERVOIR.

quantity passing through the meter was equal to the gas made by the producer. Starting with the holder full, the producer was suddenly cut out, and then the time taken for the holder to fall was noted, and simultaneous readings of the gas meter were taken.

During the producer test the total quantity of gas made was determined from the difference between the initial and final readings of the gas meter corrected according to the calibration by the gas holder. The height of the gas holder was measured at the beginning and end of each test, and an allowance made for the gas stored or discharged by the holder during the test. Each half-hour the calorific value of the gas was measured by a Junker calorimeter, and simultaneous analyses of the gas were made by absorption gas analysis apparatus.

The gas results have been reduced to a standard temperature of 60° F., and a standard pressure of 30° mercury. The gas meter was rather limited in capacity, and in order to enable it to pass the full amount of gas from one of the large producers it was necessary to weight the holder. This would have the effect of increasing the back pressure on the gas plant, but from the results it would appear that this did not make very much difference. A summary of the results of the gas producer tests is given in Table I. The fuel used under the boilers was estimated during each test. Ordinary good-quality anthracite was used in the producers, the calorific value of which was given as 14,600 B.T.U. per pound.

Pump Tests.—As in the case of the producers, each pump was tested for a period of six hours, but owing to the necessity for making both gas measurements and water measurements intermittently, six complete tests were made during the six hours, the average of these being taken for the official figure. The time occupied by each short test was about 10 to 15 minutes, but excepting once or twice when there was shortage of water the pumps worked continuously over the test period.

Quantity of Water Pumped.—On reference to Fig. 1 it will be seen that the channel from which the water flows to the pumps is straight for a considerable length. This channel is also of uniform cross section, and, therefore, floats could be used to ascertain the mean velocity of water in the channel. Each float comprised two copper balls connected by a piece of chain (Fig. 3), the lower ball being filled with water so that when in the stream the lighter ball would be practically submerged, a small part only projecting above the surface. The bottom ball would hang at a distance from the surface depending upon the length of the chain. This length was altered according to the depth of the stream on the different days on which the tests were made so that the lower ball should be about 4in. from the bottom of the channel. A number of these floats were connected together by a wood lath as shown in Fig. 4, the wood lath being attached to the chains at equal distances from the top and bottom balls. In the case of pump No. 5 only three floats were connected together in this way, whilst in the case of the four large pumps, Nos. 1, 2, 3, and 4, five floats were used, 10ft. apart. An attempt was made with floats not connected together with a wood lath, but the results were not so uniform, whereas when the floats were connected the results were quite consistent.

A distance was measured off along the channel, and cords stretched across at right angles with the stream. The connected floats were then released at a point about 6ft. or 7ft. nearer the River Lee than the first string *a a*, Fig. 1, and the time was noted when the centre ball passed this string, and again noted when the centre ball passed the second string, *b b*, Fig. 1. During the passage of the floats from *a-a* to *b-b*, any tendency for the floats to approach nearer to the one side of the stream than the other was checked by a gentle pull normal with the stream, but in such a manner as not to interfere with the motion down the stream. In nearly all cases it was found that the velocity on the left hand side of the stream was slightly greater than that on the right hand side, but by taking the reading from the centre ball no error arises on this account. During most of the tests it was possible to obtain two water readings. The total time taken by these readings corresponded almost exactly with the time taken to make one gas reading, *i.e.*, to measure the fall of the gas holder from the top to the bottom position.

Measurement of Lift.—The height to which the water was pumped was very conveniently measured by means of a mercury gauge. Fig. 2 shows diagrammatically the apparatus, which consists merely of a U tube, the top of one limb being connected to the water tower, and the top of the other limb being led down into the water in the suction pit. Effective means were used to ensure that all air was expelled from the U tube and pipe connections, and a scale was prepared divided into principal divisions, so that each division was equal to $\frac{1}{s-1}$ ft., s being the specific gravity of mercury. By measuring the difference in the level of the mercury in the two limbs in terms of the principal divisions as units, the reading gave the difference in level between the water level in the pump pit and the water level in the tower in feet of water. During the working of the pump, fluctuations of level

occur both in the pump pit and in the water tower, but by partially closing the small pinch-cock at *b*, Fig. 2, the oscillations of the mercury were so damped out that the reading then gave the true average head.

Gas Measurement.—The exact cross-section area of the gas holder was previously determined, and the volume for a given rise or fall was thus known. While a pump under test was work-

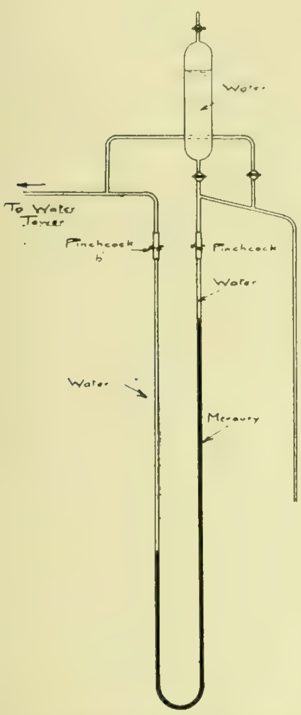


FIG. 2.—GAUGE FOR MEASURING LIFT OF PUMP.

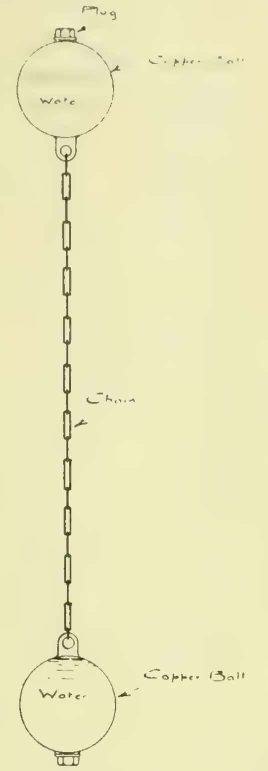


FIG. 3.—FLOAT.

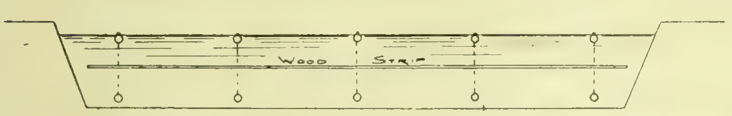


FIG. 4.—SECTION OF INTAKE SHOWING ARRANGEMENT OF FLOATS FOR MEASURING QUANTITY OF WATER DELIVERED BY PUMPS.

ing steadily the time taken for the holder to fall a definite distance was observed, and the rate of gas consumption thus ascertained. During each test the pump was supplied solely from the holder. In some cases intermediate time readings were also taken. Generally, as already observed, it was possible to obtain two water velocity readings, whilst the holder was falling during each of the short tests, and the first reading taken on the gas holder was approximately the time at which the floats started their first run over the measured distance, whilst the last gas-holder reading was taken at approximately the time at which the floats finished their second run. The temperature, pressure, and calorific value of the gas were measured for each holder full of gas. The same Junker calorimeter and also the same gas analysis absorption apparatus were employed for this purpose as were used in the gas-producer tests.

In addition to the figures required for the fuel-consumption tests, various other readings were made, such as the number of explosions per minute, the mean water level in the pump pits, the setting of the ignition, and the adjustment of the gas valves. Also indicator diagrams were taken to record the explosion pressures and the cushion pressures during the respective tests. A summary of the results of the pump tests is given in Table II., while a typical indicator diagram is shown on Fig. 5. It is to be noted that the indicator drum was turned by hand. The horizontal scale has therefore no meaning and the diagram is intended simply to show the pressure attained.

For the Chief Engineer and on behalf of the Metropolitan Water Board, the tests were carried out by: Mr. Deverell, M.Inst.C.E., resident engineer at Chingford; Mr. Whinnerah, engineer-in-charge; Mr. Warburton, chief chemist, Tottenham Gasworks; Mr. Trembarth, assistant resident engineer; Mr. Gardiner, assistant chemist; Mr. Deverell, jun., assistant engineer. On behalf of Messrs. Dowson & Mason Gas Plant Company, Ltd., Mr. White, London manager, and Mr. Webb, assistant, attended and watched the trials. On behalf of the Pump and Power Company, Ltd., Mr. W. J. Rundell, A.C.G.I., technical manager of the company; Mr. E. A. Nicholls, B.Sc., assistant engineer; Mr. H. S. Carpenter, A.M.I.M.E., assistant engineer; Mr. B. C. Carter, A.R.C.S., assistant engineer, took a complete set of observations and measurements independently of the Water Board's official representatives.

For the determination of the calorific value of the gas a Junker calorimeter was used by the Metropolitan Water Board, whilst the Pump and Power Company first obtained the gas analysis by means of an absorption apparatus, and then calculated the heat value. Both determinations are therefore included. Otherwise the two sets of readings agreed so well together that only those taken by the Metropolitan Water Board's representatives have been given in this report.

TABLE I.—*Summary of Results.*

Producer Tests of Humphrey Pumping Plant, King George V. Reservoir, Chingford, June, 1913.

Producer No.		1	2	3	4
Date		June 9	June 5	June 2	June 10
Duration of test—hours		6	6	6	6
Anthracite used during test—lbs.		2,031	2,024	2,002	854
Anthracite used per hour—lbs.		338·5	337·3	333·6	142·3
Temperature of gas ° C.		17·1	20·5	21·0	17·1
Pressure of gas—inches mercury		30·35	29·97	30·2	29·96
Gas made at 60° Fah. and 30″ Hg.—cub. ft.		166,389	166,736	171,244	67,140
Gas made per lb. coal—cub. ft.		81·9	82·4	85·5	78·6
Gas made per hour—cub. ft.		27,732	27,789	28,540	11,190
Average calorific value B.T.U. per cub. ft.: Higher		157·9	155·1	155·7	156·4
Lower		147·4	145·0	145·9	146·8
Average analysis of gas per cent. by volume.	CO_2	5·7	5·8	5·8	5·2
	O_2	0·2	0·4	0·5	0·4
	CO	24·3	24·8	25·2	25·0
	H_2	19·5	19·5	18·3	18·3
	CH_4	1·8	1·5	1·5	2·0
	N_2	48·5	48·0	48·7	49·1
Average boiler press—lbs. /sq. in.		54·7	55·7	50·5	54·7
Weight of coke used in boiler—lbs.		303	279	319	88

Remarks.—The average of these test results shows that 1lb. of anthracite yields 82·1 cub. ft. of gas at a temperature of 60° Fah. and a pressure of 30in. of mercury, at an average calorific lower value of 146·3 B.T.U. per cub. ft., that is, 1lb. of anthracite converted into gas yields 12,011 B.T.U.

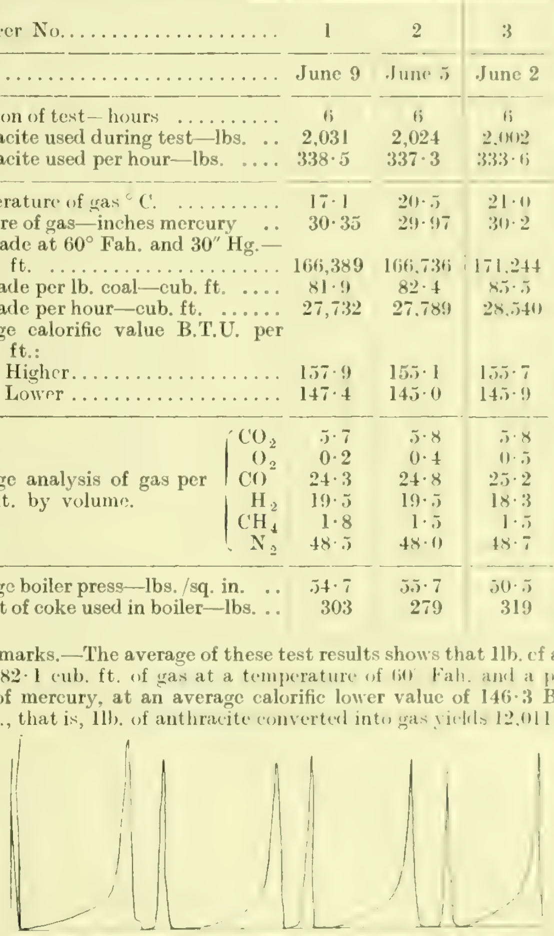


FIG. 5.—TEST NO. 4, JUNE 22ND, 1913. PUMP NO. 3. SPRING [illegible].

TABLE II.—*Tests of Humphrey Pumping Plant, King George V. Reservoir, Chingford.*

Summary of Results of Pump Tests.

Pump No.	1	2	3	4	5
Number of Tests	6	6	6	6	6
Average duration of tests—minutes	9·27	8·95	8·37	9·67	10·0
Lift in feet	30·01	30·24	30·06	32·6	30·24
Water pumped—Galls. minute	33,407	32,773	33,047	32,663	18,116
P.H.P. Developed	303·9	300·4	301·1	322·7	166·0
Gas used per minute at 60 Fah. and 30″ mercury, cub. ft.	395·4	393·3	391·5	400·1	191·6
Calorific (lower) value of gas—B.T.U. cub. ft.	145·7	146·4	146·2	142·2	138·1
Average thermal efficiency, per cent.	22·39	22·19	22·33	24·07	26·63
Anthracite used per P.H.P. hour, lbs.	·946	·957	·949	·881	·796

THE PREPARATION OF ENGINEERING REPORTS.*

BY EDWARD B. STEPHENSON.

An essential part of the work of an engineer consists in making a formal report on some project under consideration. This may be only a short record in a notebook or it may be a report on a technical investigation of some great project. In any case it must include a certain amount of data with description, and the availability of this information depends to a large extent on the manner and form in which it is presented. Now skill in writing a report is no more an inherent faculty than is skill in integrating a differential equation. It is an acquired art. Too many reports are like a low-grade ore, the amount of valuable material finally obtained does not pay for the labour necessary to extract it. Viewed solely from the efficiency standpoint it pays to have the writer put considerable time and study on the composition of his report. It is really quite morally reprehensible for a conservationist, such as every engineer should be, to waste the reader's time when more care and attention on the part of the writer would have made such waste unnecessary. To determine what this better form is requires a technical knowledge of the subject of composition and also a mastery of the subject matter and practice in actually presenting it.

The character of an engineering report must, in general, be determined by a consideration of the persons to whom the report is to be made. The business man who consults an engineer in regard to some project desires an authoritative opinion on a technical matter which only an expert can understand. The detailed facts and the method of reasoning by which the conclusions are reached are of minor importance. A report to him must be in reasonably non-technical language with such facts and arguments as will appeal to his common sense and general type of mind. To say that a perpetual-motion machine is impossible because it would violate the second law of thermodynamics is a perfectly satisfactory statement to a physicist, but it would hardly appeal to the man on the street. On the other hand, when a chief engineer requests a report from an assistant, he wants carefully prepared and analysed data and is fundamentally interested in the methods of investigation and detailed facts obtained, for on these he wishes to form his own expert opinion.

What then are the essential qualities of an engineering report? First, it should consist of a large proportion of experimental facts. Second, these facts should be carefully analysed and conveniently presented. Third, there should be more or less elaborate discussion of the theory involved in the work and of the conclusions to be drawn from the facts presented. Fourth, the style of composition should be direct and forceful with no attempt at fine writing. Glittering generalities should be eliminated as prima facie evidence of a lack of exact knowledge and each sentence should be carefully inspected for superfluous words.

The introduction to a report should contain a concise statement of the object of the investigation, with any necessary explanation of the reason for undertaking it, and with some reference to previous work in the same line or any special conditions that may exist. The reader should be able to decide from the introduction whether or not he cares to read the whole article or book.

Nearly every report requires a certain amount of descriptive matter—description of apparatus, object tested or work constructed—and the dominant idea should be to give the reader as comprehensive a grasp of the subject as possible in the easiest and quickest way. The present tendency is away from long pages of written description and toward a greater use of diagrammatic drawings, free-hand sketches, and photographs. A diagrammatic drawing of good proportion and freely lettered is generally better than a page of description. It is useful for a comprehensive view of the whole and at the same time permits a close study of any particular point without having to go through the whole description.

The written part of the description is simplified by references to the drawings and photographs, and detailed dimensions, &c., should generally be given on the drawings and not written out unless some legal requirement makes it necessary. The description should follow some definite order, possibly that in which the apparatus functions or in which the work was constructed, and in it such technical terms as will be used later should be defined.

The experimental method by which a theoretical point is to be tested is always more or less independent of the theory, and this should be kept in mind when writing the report. In using methods or theory that are not strictly original the writer should give full reference to the original sources, unless the information is common knowledge. If the investigation covers a number of different lines it is advisable to separate them under distinct headings for clearness of presentation. It also frequently happens that a reader is interested in only one phase of the subject and this separation enables him to follow that phase in detail without having to read the whole report.

From the scientific point of view the original data are by far the most valuable and should always be carefully preserved, but for a formal report the limitations of time and space frequently necessitate some generalisation or derived results. The presentation of data in their most available form is a problem worthy of very hard study. The plotting of data in the form of curves is a very common mothed to the scientist, but in non technical writing it seems to be almost unknown. Considerable experience has shown, too, that it takes a year's hard drilling to teach the average sophomore to plot his data intelligently with a proper choice of co-ordinate scale and with some regard for the usual conventions. The curve is also useful as a means of averaging data, as an indication of the accuracy of readings, as a suggestion of the general law governing the relation of the variables, and for calling attention to particular points that may require closer investigation, but its most important function is to give at one glance the whole course of the related phenomena, thus reducing the written description to comment on the most interesting features.

Another point which should always be covered in an engineering report is the accuracy with which the experimental work is done. Accuracy is purely a relative matter, and the engineer must learn to judge how accurately his work should be done. In levelling for the foundation of a shed a few inches off level would not be a serious matter, but in setting a large telescope, one hundredth of an inch variation might be inadmissible. Work should therefore be done with an accuracy that is determined by the conditions or object of the work. There are certain standards and conventions that should be understood in this connection. In writing a number there is a well-established convention that as many, but no more, significant figures should be given than the writer claims the accuracy of his data warrants. Thus writing the radius of a circle as 10 cm. means that 10 is the nearest whole number and that the exact value may lie between 9·6 cm. and 10·4 cm. If, however, the number is given as 10·0 the second cipher has the meaning that the measurement was made to tenths of a centimetre and lies between 9·96 cm. and 10·04 cm. There is a possible error in the first case of 5 per cent., and in the second case of 0·5 per cent. The location of the decimal point is merely an indication of the units used and not of the percentage accuracy. Thus the numbers of 12·3 cm., 123 mm., 0·000123 km. all have the same number of significant figures and the same percentage accuracy, although the last one is carried to six places of decimals. In physical measurements we must discard the mathematical idea of absolute accuracy and learn that any measurement is only an approximation, that it takes careful work to get four significant figures, and that six or seven figures are obtained only in a standardisation laboratory. The ciphers before a number serve only to locate the decimal point and are not significant figures, but ciphers after the number are significant and indicate its accuracy.

Another important point is, that as a chain is no stronger than its weakest link, so a calculated result is no better than the last accurate factor or term in the calculation. For instance, in calculating the circumference of a circle whose radius is measured as 10 cm. it is quite absurd to use $\pi = 3{\cdot}1416$, because the possible 5 per cent. error in the measurement of the radius, as shown above, is so large that $\pi = 3\frac{1}{7}$ or $\pi = 3{\cdot}1$ is as accurate as the measurement of the radius. A large per cent. of the labour of numerical calculation is absolutely wasted because of this lack of a proper knowledge of when to drop the figures that have no significance, and the appearance of accuracy that the retention of all the figures gives is misleading.

* Abstract from "The Quarterly Journal of the University of North Dakota," October, 1913.

The conclusions should be grouped under a few main points and should be as brief and clear cut as is consistent with accuracy. In case of a long report it may be advisable briefly to summarise the evidence on which each conclusion is based, with page references to the details.

WATER SOFTENING AND PURIFICATION.*

BY H. J. DE Q. LENFESTEY, F.C.S.

In a general way, all water is impure. Chemically pure water is composed of two gases, namely, oxygen and hydrogen, united together in the proportion of two parts by volume of hydrogen to one part by volume of oxygen, or one part by weight of hydrogen to eight parts by weight of oxygen. The first source of all natural water is the sea. By heat the water of the ocean is subjected to continual evaporation, rendering the air more or less humid. Hence the atmosphere contains aqueous vapour, but in quantities varying greatly, according to a condition of the atmosphere known as its hygrometric state. The hygrometric condition is the ratio between the pressure of water vapour and the temperature of the atmosphere. The air can contain only a certain definite quantity of moisture or of water vapour at a given temperature and pressure. The humidity of the atmosphere is therefore limited, and when that limit is reached the air is said to be saturated. When this point is reached, the surplus is condensed and falls back on the earth in the form of rain to undergo anew the process of evaporation.

Rain water is the purest form of water met with in nature, though rain water is never pure, for in passage through the atmosphere it dissolves gases of atmospheric origin, and the amount of such gases held in solution depends on the composition of the air through which the rain falls. Among the gases found in solution in rain water are oxygen, nitrogen, and carbonic acid. The organic matter which is also found in the air is carried down by rain, and the quantity of this organic matter is greater in the vicinity of industrial centres. The presence of this organic matter makes it extremely difficult to preserve rain water, because of the objectionable transformation such matter undergoes. As the result such water may be rendered unfit for domestic purposes, and injurious even in industrial operations. Charged thus with the constituents of the atmosphere, the water falls on to the rock of the earth's crust, where its chemical action, exerted on the different bodies of which that envelope is composed, is the cause of various phenomena of transformation and disintegration. It is owing to the presence of these gases, and more especially to the further supply of carbonic acid which it takes up in its passage over the earth's crust, that the water is able to penetrate the rocks and exercise its powers of destruction and decomposition of even the hardest of them. This carbonic acid is produced by the decomposition of organic matter, as shown by Boussingault, or is the effect of the oxidation of combustible matter, or by the action of acids on limestone rock. The different substances in solution which have this destructive power on rock are likewise the cause of corrosion in steam boilers and of iron generally.

It is easy to understand that if water is capable of such vigorous action in nature, it must necessarily display similar energy in industrial uses, and even be able to get the better of substances endowed with a maximum of resisting power. Charged with oxygen and carbonic acid and organic matter, in its action on the rocks, water can convert anhydrous bodies into hydrates, dissolve mineral matter, produce carbonates, and separate the metals from the substances combined with them. We are all accustomed to divide waters into two classes—soft waters, containing relatively very small quantities of the salts of lime and magnesia in solution, and hard waters containing relatively large quantities of these salts in solution. Dr. Frankland states that as a rule the following formations give soft waters:—

Igneous.	Coal measures (non-calcareous).
Metamorphic.	Lower greensand.
Cambrian.	London and Oxford clay.
Silurian (non-calcareous).	Bagshot sands.
Devonian (non-calcareous).	Non-calcareous gravel.
Millstone grit.	

* Abstract of Lecture delivered before the Nottingham Engineering Society.

On the other hand, the following formations almost invariably yield hard waters:—

Silurian (calcareous).	Conglomerate (sandstone).
Devonian (calcareous).	Lias.
Mountain limestone.	Oolites.
Coal measures (calcareous).	Upper Greensandstone.
New red sandstone.	Chalk.

In addition to the geological character of the land, a most potent factor in the production of hard waters, and water unsuitable for boiler and other purposes, is the pollution of streams and canals by the various works situated on their banks. Not infrequently, substances more objectionable than mere scale formers are allowed to mix with the water traversing a manufacturing district.

We will now proceed to investigate the action of the rain from the time it falls on the earth's crust. Owing to the porous nature of the rocks which form the earth's crust, and to the cracks and faults occurring in them, the water falling on the surface of the earth is able to penetrate into the ground. This water, charged with carbonic acid gas and oxygen, has a powerful disintegrating action on the material of the rocks, some of the constituents of which are chemically attached and carried away in solution. In this way the hardest rocks are worn away. By reason of the principle, by virtue of which water always seeks the lowest level, these waters in their passage into the depths of the earth absorb more and more carbonic acid gas from the abundant supply afforded by organic matter. The water being thus strengthened by this fresh supply of carbonic acid gas, the phenomena of chemical activity becomes more and more marked. As a consequence of the phenomena of oxidation, carbonation and decomposition produced by the excess of carbonic acid, the water loses more and more of these gases, especially the carbonic acid, which dissolves the limestone rocks with the greatest ease. Having reached an impervious bed, the passage of the water downwards into the earth is arrested, and it here collects and forms subterranean pools. These subterranean pools are sometimes of very great capacity, and the water eventually emerges again in the form of a spring. By sinking a shaft in the ground to the water line a well is formed. If the spot at which the shaft is sunk is at a level considerably lower than the highest point of the water containing stratum, the water spurts out as an artesian well.

The composition of a well or spring water varies according to the strata through which the water has percolated. Ordinary well-water frequently contains a considerable quantity of the carbonates and sulphates of calcium and magnesium which renders it unsuitable for industrial and domestic purposes. In the case of shallow wells the water often gives off a marked odour of sulphuretted hydrogen, arising from the formation of sulphides by the reduction of calcium sulphate in presence of organic matter in the water. When the organic matter has become nitrogenised it is liable to be transformed, under the influence of certain ferments, into compounds of nitrogen, such as nitrites, nitrates, and ammonia. After issuing from the earth in the form of springs the water now pursues its way over the surface of the earth, and carries off, by the mechanical action of its current, the material of which the surface is composed. The streamlets then formed combine and develop into brooks, and these in turn swell into rivers, which eventually run into the sea, sweeping with them all the matter collected in their course.

Water which takes up carbonic acid so readily will often just as readily release it. In nature the liberation of the carbonic acid is brought about by the action of the water on other rocks, or is brought about by the action of marine organisms, and the final outcome is the deposit of carbonate of lime or magnesia. Thus in the steam boiler, on boiling, the water releases the carbonic acid, and calcium carbonate is deposited in the form of scale. Calcium sulphate enters into the composition of water from the solvent action of the latter in gypsious beds, and its frequence is experienced by the wide distribution of this kind of strata. The greater the quantity of calcium sulphate in solution the more unsuitable is the water for industrial and domestic purposes. Sulphate waters do not liberate calcium and magnesium sulphate when coming into contact with the air, but have to undergo special

treatment in order to free them from these objectionable salts.

After certain special phenomena of oxidation have taken place in the rocks beneath the surface, the pyrites or sulphides are converted by means of oxygen into sulphate of iron:—

$$2\,FeS + 2H_2O + 9O = 2H_2SO_4 + Fe_2O_3$$

This oxidation of pyrites which takes place in the presence of water charged with air eventually results in the production of basic ferric sulphate, which precipitates on the adjacent rocks normal ferric sulphate and free sulphuric acid, which the water carries off in solution.

$$6\,FeS_2H_2O + 27O = (Fe_2O_3)_2\,SO_3 + Fe_2\,(SO_4)_3 + 2H_2\,SO_4$$

Having endeavoured to show the means by which the most commonly found salts find their way into water, I shall now proceed to consider the effects which various salts found in water have in industrial processes. The salts which produce hardness in water are the following:—

Carbonates of lime and magnesia.
Sulphates of lime and magnesia.
Chlorides of lime and magnesia.
Nitrates of lime and magnesia.

The hardness of water is generally considered under two heads, namely, temporary and permanent. The temporary hardness is that due to the carbonates of lime and magnesia, which are held in solution by carbonic acid, and which are thrown out of solution on boiling the water. The permanent hardness is due to the sulphates, chlorides, and nitrates of calcium and magnesia, and these salts are not deposited when the water is boiled under ordinary atmospheric pressure. The solubility of calcium and magnesium carbonate is chiefly due to the presence of carbonic acid, and these salts are present in water in the form of bicarbonates. Calcium carbonate is soluble only to the extent of about 1½ grains per gallon in water free from carbonic acid, but magnesium carbonate is more soluble, being soluble to the extent of seven grains per gallon. It will thus be seen that when a water containing the carbonates of lime and magnesia is used for boiler purposes without previous treatment, practically the whole of these salts are deposited inside the boiler in the form of scale. When present by itself calcium carbonate does not tend to form much scale in a boiler of the Lancashire type, but deposits in the form of mud. In a water-tube boiler, however, it very soon completely blocks up the tubes, and it will form a very hard scale in economisers. Calcium sulphate is very soluble in water, its maximum solubility being the temperature of 95° Fah., when it is soluble to the extent of 177·8 grains per gallon. The solubility gradually increases up to this point, and then gradually decreases, and at a temperature of 464° Fah., corresponding to a pressure of 484lbs. per square inch, it is soluble only to the extent of 12·6 grains per gallon. This table will show the solubility of calcium sulphate corresponding to different temperatures and pressures:—

Temp. F.	Steam Pressure. lb. per sq. inch.	Solubility of Co.SO4 in grains per gallon.
32·	—	143·5
40·	—	—
59·	-	—
68·	—	168·7
95·	—	177·8
111·	—	—
158·	—	170·8
212·	0	151·0
284·	37	54·6
323·6	79	39·2
256·	131	18·9
464·	484	12·6

Calcium sulphate gives endless trouble when present in feed water of a boiler working at a high pressure. Calcium sulphate is deposited on the boiler plates and forms a scale of a crystalline nature as hard as flint, which can only be removed by chipping, which does damage to the boiler plates. Moreover, calcium sulphate is an exceedingly bad conductor of heat, and a scale formed of calcium sulphate will cause the boiler plates to become very much overheated, thus resulting in severe strains and shortening of the life of the boiler.

Rankine gives this table of resistance to passage of heat of various substances:—

	Per cent.
Wrought iron	1
Copper	3·4
Slate	9·5
Brick	16·7
Calcium carbonate	17·0
Calcium sulphate	41·0

It will thus be readily seen that a scale formed by a water containing salts of lime in solution will not only cause serious overheating of the boiler plates, but will also be responsible for the wastage of fuel.

Magnesium sulphate and the chlorides and nitrates of lime and magnesia, owing to their very great solubility, do not of themselves form scale, but by double decomposition taking place between the magnesium salts and calcium carbonate present in the water, magnesia enters very largely into the composition of scales, as will be readily seen from the following analyses:—

Analysis of a Well Water.

	(East London) Grs. per gall.
Calcium carbonate	30·00
Magnesium carbonate	3·02
Magnesium sulphate	6·00
Magnesium chloride	17·95
Sodium chloride	132·10
Silica	0·73
Oxide of iron	0·93
	190·73

Scale Formed from Above.

	Per cent.
Calcium carbonate	22·29
Calcium sulphate	22·98
Magnesium hydrate	46·29
Silica, &c.	2·98
Oxide of iron, &c.	3·83
Organic or volatile matter	2·05
	100·42

Analysis of Water from South Wales.

	Grs. per gall.
Calcium carbonate	4·50
Calcium sulphate	3·91
Magnesium sulphate	5·25
Sodium sulphate	1·84
Sodium chloride	2·06
Silica	0·33
Oxide of iron	0·23
	18·12

Scale Formed from Same.

	Per cent.
Calcium sulphate	51·58
Magnesium sulphate	1·05
Magnesium hydrate	35·25
Silica, &c.	6·43
Oxide of iron, &c.	1·35
Grease	2·60
Other volatile or organic matter	1·64
	99·90

In both cases, the large proportion of magnesium hydrate in the scales will be noticed, and in the first case the appearance of a large amount of calcium sulphate, though the water contained none. In the second place, the most striking point is the disappearance of calcium carbonate from the scale, in spite of the considerable proportion found in the water. Although magnesium sulphate, chloride, and nitrate do not themselves form scale, yet their presence in boiler feed water may lead to very much more serious results than the mere formation of scale. By concentrating a solution of magnesium chloride colourless needles or extremely deliquescent

orthorhombic crystals are obtained, of the formula $MgCl_2 + 6H_2O$.

On heating these crystals of hydrated magnesium chloride to 106° C. dissociation into hydrochloric acid takes place $MgCl_2 + H_2O = MgO + 2HCl$.

This dissociation of magnesium chloride into hydrochloric acid is attended with injurious consequences in industrial operations, a striking instance being the corrosion of steam boilers. Water containing magnesium chloride in solution produces corrosion more or less extensively according to the quantity of that salt present. The fact that magnesium chloride is absent in the feed water does not ensure immunity from this danger in the boiler, as magnesium chloride may be produced, as the result of double decomposition, if magnesium sulphate is in the presence of other chlorides in water. Magnesium nitrate is also decomposed at high pressure particularly in contact with iron, nitric acid being liberated, and this, of course, causes very serious corrosion in the boiler.

Sodium chloride and sodium sulphate are salts which are found in most natural waters, but unless the concentration is allowed to become high, no trouble is experienced with these salts in water, as they are very stable and are also very soluble in water.

There remains two classes of water to be considered before I pass on to the various remedies in use for the prevention of scale, namely, acid waters, and waters that owe their alkalinity to the carbonate of soda. Most waters, owing to the presence of calcium carbonate and magnesium carbonate, are alkaline, and it is usual to express the alkalinity in terms of so many grains per gallon of calcium carbonate. When, however, the gathering ground of a natural water consists of the primary rocks, contiguous to a large industrial centre, an acid water not infrequently results. These waters, owing to the insoluble character of the primary rocks, are invariably very soft, the lime salts dissolved being insufficient to neutralise the small amount of acid absorbed from the atmosphere, due to chemical works and the combustion of sulphurous coal. Such a water would prove highly corrosive if used in a boiler without the neutralisation of the small amount of free acid. Water in moorland districts, although at times it is neutral, is liable to become distinctly acid. These waters are not only dangerous to use for boiler purposes, but are exceedingly dangerous to the public health owing to the property of such waters to dissolve lead. Moist peat is invariably acid. Peat which has dried rapidly develops acidity when again moistened. The acids which are characteristically present are humic and crenic, and they are by-products of the vitality of certain bacilli. Dr. Houston found that during dry weather—markedly after some continuance of drought—moorland waters show no acidity and lose their lead-dissolving potency. On the other hand, a downfall of rain soaks through the beds of acid-laden peat, and descends to the water courses in quantity, making the general supply acid and plumbo-solvent. It follows from this that the greatest attention should be paid to moorland supplies in wet weather. The experiments carried out under Dr. Houston's direction with the Shipley water supply during two years following February, 1894, are of great interest. The reservoir water was always acid, and the amount of lead dissolved in a given time by a measured quantity of it was found to be directly proportional to the degree of acidity. The solvent action was pronounced, for about two grains of lead could be taken up per gallon during three minutes' contact with lead-shot. The quantity dissolved in this way varied from time to time, always keeping pace with the acidity and ranging from 1-4 grains per gallon.

The power of moist peat to confer plumbo-solvency upon distilled water and consequently on rain water is remarkable, for if a grain weight of peat is submerged in water it is capable of rendering 20 times its own weight of the water decidedly plumbo-solvent. By suitably devised experiments, Dr. Houston proved that with alternate drying and submerging, peat might confer dangerous acidity on 200 times its own weight of water.

Waters pumped from mines, owing to long contact with sulphurous coal, are frequently of an acid nature, and most corrosive in their action on the plates of a boiler. Alkaline waters, owning their alkalinity to carbonate of soda, are occasionally met with as natural waters, and are very objectionable for use for boiler purposes. The following is an analysis of such a water from an artesian well:—

	Grs. per gall.
Carbonate of lime	11·5
Carbonate of magnesia	7·8
Sodium chloride	6·4
Sodium nitrate	0·2
Sodium sulphate	4·8
Sodium carbonate	8·3
	39·0

This water attacked the fittings of the boilers and caused excessive priming.

A concentrated solution of carbonate of soda rapidly attacks boiler fittings. The small amount of copper dissolved from the latter in contact with the iron plates is in its turn precipitated, an equivalent quantity of iron passing into solution. With concentrated alkaline waters a series of reactions may thus be set up, which will rapidly produce pitting of the plates.

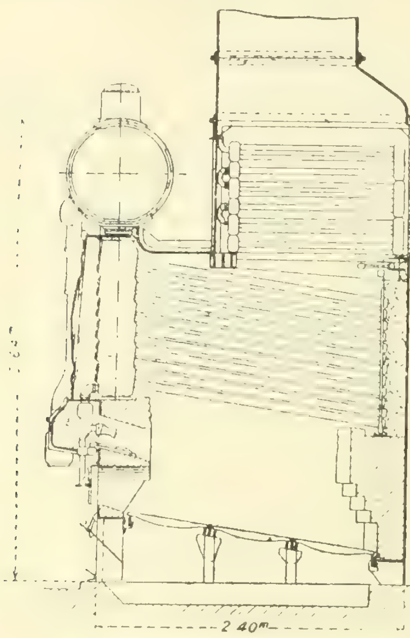
Another very serious impurity sometimes found in boiler feed water is oil and grease. Oil is frequently introduced into feed water by using exhaust steam for heating the feed by bringing the exhaust into direct contact with the water. Oil is frequently introduced into the boiler also by the use of surface condenser or jet condenser water. Oil is sometimes present in astonishing quantities, and is a most fruitful source of trouble. On passing into the boiler the oil floats as scum on the surface of the water, gradually becoming entangled with particles of carbonate of lime and sulphate of lime which are continually separating from the water. When the scum attains the same specific gravity as the water, it is circulated by the boiler currents until it meets with some surface to which it fastens, forming an incrustation on the flue or shell of the boiler. The deposit thus formed is an effective non-conductor of heat and a most frequent cause of overheating and consequent collapse of the boiler. It is stated on the authority of the highest engineering officials of the British Navy that even when only a minute proportion of oil or grease is present in the feed water, a decided falling off of the evaporative efficiency of the boilers is noticed, distinctly traceable to this cause. The effects of oil have sometimes been very rapidly and unexpectedly manifested, as in the following actual case. A new steamer had undergone several steam trials, during which the arrangements for removing oil from the feed water, although duly provided, had been neglected and not brought into service, a neglect the consequences of which were aggravated by the very large amount of lubricant always requisite with perfectly new engines. The oil therefore passed freely into the boilers and accumulated there in considerable quantity. During the periods of rest between the different trials it rose to the surface of the water, and formed a layer, the presence of which was unsuspected. Before the final trial it was decided to empty the boilers and refill them with fresh water. This was accordingly done, the water was run off, and consequently the oil came into contact with all the internal surfaces and coated them thickly. When the boilers were re-filled, the greasy coating adhered to and remained upon the surfaces. The result was a sudden interruption of the final trial. The steamer returned to the dock with eight collapsed furnaces, and the cause became clearly evident during the investigation which followed.

(To be continued.)

Martell Scholarship.— The secretary of the Institution of Naval Architects announces that applications for a Martell Scholarship in Naval Architecture, 1914, must be sent in before February 1st next. The scholarship, which is of the annual value of £100 and is tenable for three years, is won by competition, and candidates must be between the ages of 18 and 21 years, and have been continuously employed on naval architecture for two years. Further particulars can be obtained from the Secretary, 5, Adelphi Terrace, E.C.

NICLAUSSE MARINE WATER-TUBE BOILERS.

The French Admiralty have, says "The Times" Engineering Supplement, placed an order with Messrs. J. & A. Niclausse, of Paris, for 21 boilers aggregating 36,000 h.p. for the new 25,000-ton Dreadnought "Bearn" now being laid down. According to our contemporary, these boilers will be of a type specially designed to give high capacity in relation to weight and space occupied, and capable of exceptionally high rates of combustion when fired with coal, briquettes, or oil. They will embody an improved arrangement of feed distribution whereby the feed to the lower tubes exposed to the most intense heat of the furnace is purified and brought to boiler steam temperature by being previously passed through the upper tubes, where the temperature is insufficient to produce hard scale and deposit is consequently harmless. In addition, a new form of economiser is placed above the evaporating system,



Niclausse Marine Water-tube Boiler.

the height of which is slightly reduced. It consists of 780 40 mm. tubes arranged in 15 horizontal elements each forming a U. Each element consists of a single header at the back and two headers at the front, one for the entrance and the other for the exit of the water, which flows into the header at the point corresponding exactly to the exit of the combustion gases and leaves at the point corresponding to their entrance. The elements are joined at the front by connecting pipes so as to ensure circulation in the reverse direction to the combustion gases. The evaporating tubes, 456 in number, have an outside diameter of 60 mm., the lower ones being 4 mm. and the upper $2\frac{1}{2}$ mm. in thickness, and their heating surface is equivalent to 173·63 sq. m., that of the economiser being 119·22 sq. m. In a 16-hour trial of one of these boilers burning continuously 46lbs. of coal per square foot of grate area the evaporation from and at 212° Fah. was 11·91bs. of water per pound of coal, and burning oil at the rate of 28lbs. per square foot of grate area the evaporation was 16lbs. of water per pound of oil.

DIELECTRIC STRENGTH OF THIN INSULATING MATERIALS.

In a paper on the above subject recently presented before the American Institute of Electrical Engineers, Mr. F. M. Farmer gave the results of a series of tests made at the Electrical Testing Laboratories, New York City, to determine the effect of electrode area on the apparent dielectric strength of thin insulating sheets. At the present time there were, he said, no standard specifications for testing such materials and there was great divergence as to the size of the electrodes between which the sample was placed in the test. Some contended that a large electrode area more readily gave the minimum dielectric strength and that very small electrodes produced an abnormal concentration of dielectric stress. Each of the tests was made with two similar, flat, circular electrodes ranging in diameter from 0·039 cm. to 38 cm. and placed directly opposite each other. The materials tested were varnished cambric and thin sheet hard rubber in relatively dry air and moist air; varnished cambric in dry and wet oil; transformer oil with various spacings; air as a dielectric. No attempt was made to get refined quantitative results, but rather qualitative results. So many variables entered into the work that a high degree of reliability could not be expected. Although the results given in the paper were averages of a great many determinations, considerable allowance must be made in drawing final conclusions. So far as the original purpose of the tests was concerned, the following conclusions were drawn from the results. The apparent dielectric strength of insulating materials in thin sheet form was materially higher with small electrodes than with large ones. This probably applied generally to all dielectrics, gaseous, liquid, and solid, although the amount of the variation differed widely with different materials. The variation with ordinary sheet insulating materials, such as paper and cloth, might be 40 or 50 per cent. between $\frac{1}{64}$in. and 8in. or 10in. diam., while with oil under the same conditions the variation was over 1,000 per cent. The prevalent opinion was that the electrostatic stress was concentrated when the dielectric was between sharp points and that failure would occur at a low value. This appeared to be the case when the points were very sharp, such as needle points, but as soon as they had an appreciable area, the puncture value was much higher than with large electrodes. The tests emphasized a need which had been frequently pointed out, viz., standard specifications for the testing of insulating materials, especially when in the form of thin sheets. It did not seem probable that the dielectric strength of an insulating material under all working conditions could ever be predicted with exactness, but we could at least have standard methods of rating such materials so that a value for the dielectric strength would have the same significance to the manufacturer, the purchaser, and the designing engineer.

SAFEGUARDING BELTS, SHAFTS, AND PULLEYS.

The following recommendations have been issued by the Inland Steel Company with a view to prevent accidents arising from contact with moving belts, shafts, or pulleys.

(1) Belt, rope, and cable transmission should be arranged, so far as possible, to be easily guarded. (2) Pipe or angle railing placed 18in. from the pulley or belt should be provided where there is little danger of persons getting caught by the belt. (3) Wire-mesh or perforated-plate casing should be provided where the location of the belt is such that persons are liable to get caught between the belt and the pulley. (4) Where the belt is located in such a position that, should it break, flying ends will strike persons passing by the belt, it should be enclosed by a suitable guard. (5) The width of a belt should be allowed between two pulleys or a pulley and a hanger on shafting so as to prevent the belt from becoming wedged and possibly pulling down the line shafting. (6) Belt splicing should be made so as to eliminate ragged edges or projections which might catch employés' clothing. Endless belts are recommended, especially for high-speed machines. (7) Belts should be inspected frequently and kept in a condition to avoid accidents. Tight belts should be avoided. (8) Wherever it is necessary to shift belts a mechanical device should be provided. (9) Where it is necessary to unship a belt, a hook or belt-perch should be provided to prevent the belt from resting on the shaft. (10) Shafting not over 12in. above floor should be covered. (11) Shafting over 12in. and not over 7ft. above floor should be encased or railed off. (12) Exposed ends of shafting should be encased or otherwise guarded. (13) Overhead shafting which must be oiled should be equipped with a walk for the oiler, if practicable. (14) Electrically-driven shafting should be provided with a safety switch, to be used when men are working on it. This switch should be placed at the top of the ladder or in some place where no one will tamper with it. (15) Shaft couplings should be guarded where safety coupling is not used. (16) To prevent gears or pulleys from working off the ends of shafting, shaft ends should project at least the diameter of the shaft beyond the hub of the gear or pulley, so that the key can be locked in place. (17) Hangers for shafting should be particularly strong and well secured. (18) All projecting keys in

shafting when exposed so that a person might get caught thereon, should be guarded or cut off. (19) Wherever possible, cotter pins or spring washers should be provided to prevent nuts from working off the ends of bolts. (20) Set screws should be guarded, countersunk, or placed in safety collar with flanges high enough so that the set screw head will not project above the flange. (21) Because of the dangers incident to hoisting material by means of line shafting, no hoisting should be done in this manner. All hoisting should be done either with hand tackle and block, or with regular hoisting machinery.

DRIVING MECHANISM OF PLANING MACHINES.

AN arrangement of driving mechanism for planing and similar machines, requiring a reciprocating or reversing motion, the invention of Mr. T. B. Richardson, Oliver Hill, Horsforth, near Leeds, is shown in the accompanying cuts. Fig. 1 is a part-sectional end elevation, Fig. 2 a side elevation, and Fig. 3 a part-sectional plan. The table of the machine is reciprocated through the medium of a rack, worm, and driving shaft in the ordinary way. The periodic reversing motion to be imparted to the shaft A is effected through a driving and reversing mechanism comprising two differential gears B, C, respectively, carried within heavy flywheels D, E, revolubly mounted in fixed brackets. The sun wheels F, G of the gear are respectively keyed to a short shaft H and to a transmission shaft J, the shaft H being provided with a brake drum K. The sun wheels M, N of the gear C are similarly keyed respectively to a short shaft O and to the transmission shaft J, the shaft O being provided with a brake drum P. The planetary wheels of the two gears B, C are respectively mounted on transverse shafts Q, R, carried by the flywheels D, E, which latter are continuously driven in opposite directions by open and crossed belts. The motion of the transmission shaft J is imparted to the worm shaft A through the medium of a bevel pinion and bevel wheel. The brake drums K, P are each fitted with brake bands, each of which is coupled by a link to one of a pair of oppositely situated arms S fixed on a rock shaft T. This shaft is periodically rocked through the medium of tappets U, V, adjustably fixed to the reciprocatory table, and respectively adapted to engage oppositely situated projections X, Y of a swivelling boss W pivoted to the framing, which boss is formed with a cam-way engaging a runner of a crank arm Z fixed to the shaft T. This rocking of this shaft causes the oppositely situated arms S thereon to alternately tighten and release the brake bands on their brake drums K, P.

In action, the heavy flywheels D, E are continuously driven in opposite directions through the medium of their belts, and their motion is transmitted through their respective differential gears B, C to the short shafts H, O, which latter are thereby caused to revolve idly in opposite directions until the swivelling boss W is turned on its pivot so as to rock the shaft T and cause one of the arms S to tighten, say, the brake band upon the drum K, and hold the short shaft H and the sun wheel F stationary. The differential gear B now has the effect of transmitting the motion of the flywheel D to the transmission shaft J and its bevel pinion, thus causing the shaft A through its bevel wheel to be revolved in one direction and to traverse the table to the left until the tappet V engages the projection Y on the swivelling boss W, when the cam-way of the latter actuates the crank Z and turns the shaft T in its brackets, so as to rock the oppositely situated arms S simultaneously, and cause the brake band to be released from the drum K, and at the same time to tighten the other brake band upon the drum P. This action frees the short shaft H of the gear B, which now revolves idly, while the short shaft O of the gear C is held stationary, thus transmitting the motion of the flywheel E to the transmission shaft J, and thence by way of the bevel pinion and wheel to the worm shaft A, which is thus caused to revolve in the opposite direction and traverse the table to the right. On the table being traversed sufficiently to bring the tapper U into engagement with the projection X on the swivelling boss W the direction of motion is again reversed, and thus the reversing of the drive is automatically performed. It will be seen that the release of the brake at the end of each stroke enables its drum to rotate, and so removes the thrust from the table without interfering with the motion of the flywheel and its gear connected with that brake, whilst the momentum of the other flywheel and its gear acting against the momentum of the table rapidly reverses the motion of the latter. By driving the flywheels D, E at different speeds, the mechanism can be arranged to traverse the table at a greater speed in one direction than in the other.

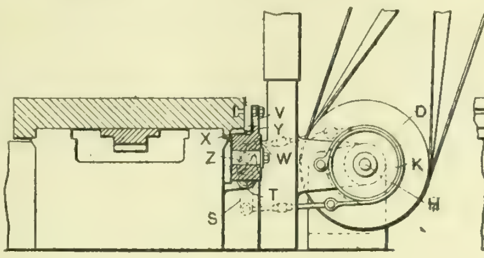


FIG. 1.

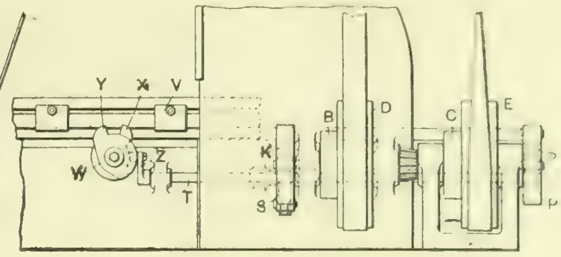


FIG. 2.

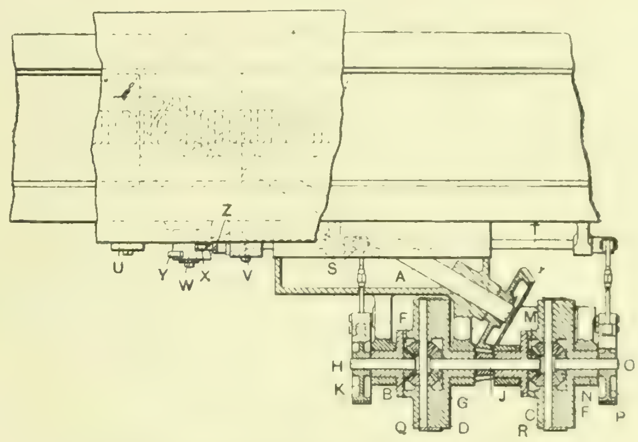


FIG. 3. DRIVING MECHANISM OF PLANING MACHINES.

THE DANGER OF EMPLOYING BOY SWITCH OPERATORS.

An inquest was held at Foleshill, on the 1st inst. on an assistant electrician at Exhall Colliery, who was killed in the mine on Dec. 22nd. The cable main in the mine was being repaired, and deceased was at work upon it. The current was turned on, and deceased received a fatal shock. In the course of the evidence a boy stated that he was told not to put the current on until it was rung for—the signal being followed by 20. He heard some ringing, and then 20, and then witness turned on the current. He admitted that he forgot he ought to have received the signal 9, as well as 20, and did not know that anything was wrong for two or three minutes, when he got a signal to turn the current off. The Coroner said it was evident some new and safer method of signalling in mines was necessary than obtained in this case, and he invited the management to devise measures of precaution. The jury returned a verdict of "Accidental death," and expressed the opinion that the boys were not properly instructed in their duties and were not proper persons to leave in charge of such an important switch. They recorded that instructions should be given to electricians that the handle should be taken out of the switch in all cases where repairs were taking place.

Firedamp Ignited by Electric Sparks.—A party of expert electrical and mining engineers, headed by Mr. Nelson, the Home Office electrical inspector, recently carried out an experiment at the rescue station at the New Tredegar Colliery, South Wales, by which it was proved beyond question that coal gas or firedamp may be ignited by sparks from the electric signalling cables used underground. In view of the Sengenhydd explosion and the enquiry relative thereto the result is regarded as extremely important.

REFRACTORIES IN THE IRON AND STEEL INDUSTRY.*

BY HARRY W. CROFT.

THE word refractories is taken to mean the materials used to resist the action of heat, slags, and gases continuously at work upon the lining of practically every furnace engaged in metallurgical operations. The briefest consideration shows their importance, when we recall that the blastfurnace and the hot blast stove are merely huge stacks of firebrick enclosed in steel shells. The open hearth is a structure of various refractories properly stayed. In such furnaces the refractories form the laboratories where heat, slags, and gases may effect their transformations.

In considering refractories we divide them into three classes: (1) Fireclay brick. (2) Silica brick. (3) Basic, or magnesite and chrome brick. Fireclays are essentially silicates of alumina, varying widely in their proportions of silica and alumina and in the content of impurities, such as lime, iron, magnesia, and alkalies. They are formed by the disintegration and decomposition of feldspathic rocks. In a general way we divide all clays geologically into two classes, those that occur in the coal measures and those of other measures. We again separate coal measure clays into two classes: the flint vein, and all the other clays occurring higher in the coal measures, known as Upper Vein Clays. The latter may be considered as solely plastic clay. As the iron and steel industry requires a large percentage of high-grade firebrick, and since the majority of these bricks are made of the coal measure flint and plastic clays, we will in discussing manufacture confine ourselves to these two clays. Various mixtures are used, ranging from about 90 per cent. of flint and 10 per cent. of plastic in the most refractory brick, to a brick of the least refractoriness, made entirely of the plastic clay.

The clays mined and properly selected are broken into small lumps, mixed in suitable proportions, and ground in the wet pan to the proper degree of fineness. The mass is then moulded into shape, tempered on a hot floor, repressed, thoroughly dried and burned at a temperature of 2,600° to 2,650° Fah. This is the old hand-made process. This brick is open, porous, and well adapted to withstand sudden changes of temperature. Many departures from this process have been tried and various machines employed in the different stages of manufacture. In many cases there has been a speedy return to the hand-made process, while in others a better brick has been developed for certain uses. In the high-grade brick, the most noticeable development in the machine-made product is in the manufacture of blastfurnace brick on a steam or other powerful press. The machine-made brick is denser by 7 to 8 per cent. than the hand-made one. Most cheaper grades of brick are made by machinery.

As to the uses and development of fireclay brick, we will consider definite examples, such as the blastfurnace, open-hearth furnace, &c., the conditions to which the brick are subjected, and how far these materials answer reasonable demands. For a blastfurnace lining three kinds of brick are made. For the hearth and bosh a brick of maximum refractoriness and one capable of resisting the action of the fused or semi-fused furnace contents; for the inwall a brick to stand high heats and abrasion; and for the top a dense and tough brick to withstand the wear of the stock and resist the action of the gases. The introduction of the water-cooled furnace, with its lining of 12in. or less, necessitates the use of the highest grade of refractories available, and the blastfurnace operator and brick manufacturer co-operated in making a brick of more uniform dimensions and of much greater density than heretofore, without sacrifice of refractoriness. This was accomplished by a mixture of clays giving the minimum of shrinkage and by manipulation designed to increase their bond to the maximum. The bricks were finally made into 12in. blocks on a steam press. The result was a lining that fulfilled the expectations of all concerned. The furnace in which this lining was put was blown out after an eight months' run, to make some slight changes in the shell. In making a 12in. lining of such great density, backed by a water-cooled jacket, there was naturally some apprehension as to whether it would spall. An examination showed that no spalling occurred. It also resisted the abrasion of the stock and channeling blast, and was practically impermeable to gases. A number of these linings have since been installed.

Several years ago a committee appointed by one of our largest iron and steel interests made an exhaustive study of refractories to combine practical operating experience with the knowledge of the brickmaker in producing, if possible, better brick. The result of their study of blastfurnace linings led to a specification for blastfurnace brick calling for a minimum of impurities and of consequently higher refractoriness than the standard linings. To produce this brick without loss of bond, the carefully-drawn specification called for special treatment in almost every department of the manufacture. Two hand-made linings were made under this specification. A few years previous to this development, at the request and with the co-operation of a well-known blastfurnace manager in the Chicago district, several linings were made, with the object of producing a lining somewhat more refractory and at the same time denser and tougher than the standard linings. These were made in a manner very similar to those just mentioned, the principal difference being in less hand picking, rehandling, and washing of clays, with a saving in cost. They also were hand made.

In summarising the three developments cited it is of interest that each of the three efforts to improve the old standard lining approached the problem from a somewhat different angle. The making of the steam-pressed linings for the thin-lined furnace aimed directly at a brick of much greater density and toughness, without sacrificing any refractoriness. The second method undertook to materially increase the refractoriness of the brick, at the same time maintaining, if possible, the bond of the standard furnace brick. The object of the third method was to increase both the refractoriness and toughness of the brick, in a lesser degree, possibly, than in the other two cases, but without materially increasing the cost.

All three are refinements of manufacture with varying degrees of additional cost. As a furnace often runs four or five years on one lining, the determination of the qualities in a new lining is naturally slow, requiring a series of runs to cover the varying conditions under which different furnaces are operated. At present blastfurnace men are calling for the hand-made and machine-made linings in about equal numbers. The present machine-made lining includes as many as possible of the good points of the first steam-pressed lining referred to, without all of the extra treatment of clays and consequent higher cost. In one point apparently the machine-made brick should be superior, and that is in furnace tops. It is also possible to make it of more regular and uniform dimensions than by the hand-made process, thus ensuring better brick-laying.

In hot blast stoves firebrick acts merely as a thermal reservoir, yet are subject to widely-varying temperatures, to enormous loads, and in many cases to the fluxing action of the flue dust in unwashed gases. Again we note a development in the use of brick of greater density and higher refractoriness, with a decided tendency to substitute a higher for a lower-grade brick. Another recent development is the use of silica brick in the flash walls and domes. This materially increased the life of the stoves where used. Although in blastfurnace and stove piping and connections high temperatures are not involved, mere density in the brick is insufficient; toughness is requisite. In recent years a high-grade brick specially designed for this use has proved economical. What we have said of stove brick applies to the checker brick used in open-hearth furnaces and soaking pits. Here again the tendency is unquestionably toward the use of a higher-grade brick.

The practice in many heating and welding furnaces is particularly severe on brick, for we encounter here extremely high temperatures and often sudden variations in temperature. Limited as we are by the refractoriness of the clays at our disposal, any substantial betterment in results must come from improved furnace design, or the substitution of silica for clay brick. A remarkable development in the use of firebrick for boiler settings has taken place in recent years. It was but a few years ago that the words boiler brick were synonymous with a second or third-grade material. To-day no fireclay brick is considered too good if it materially lengthens the service. For the sidewalls many are finding a blastfurnace brick economical, and even expensive bauxite brick is some-

* Abstract of paper read before the American Iron and Steel Institute, Chicago.

times used because of its greater resistance to clinkering. Under modern conditions of increased grate areas, mechanical stokers and forced draught, any or all of which may be involved in the common practice of working boilers from 50 per cent. to 150 per cent. over rated capacity, the problem of the boiler setting is no small one. At first sight the gas producer has no real lining problem, yet to-day certain producer manufacturers have entirely discontinued the use of other than the highest grade of brick, and are experimenting with various linings, including bauxite brick.

This brings us to the second division of our classification, namely, silica brick. In the manufacture of silica brick, care in the selection of rock is most important. At the quarry the rock is broken and at the works crushed into small pieces and ground to the proper fineness in the wet pan, 2 per cent. of lime usually being added for bond. The bricks are manufactured in a manner similar to that used in making clay brick, but are burned at a higher temperature. We believe the silica bricks of to-day are better than they were several years ago. The workmanship is better; the bricks are tougher, due to improved methods of making; and they are better annealed. The high refractoriness of this brick, its slight expansion under heat, and exceptional conductivity have increased its use in the manufacture of iron and steel enormously. It would be rash to hazard a guess as to its future possibilities.

In the open-hearth, whether basic or acid, its use is no longer restricted to the sidewalls, blocks, and roof, but is extending to the checkers, roofs, and walls of the regenerators. The marked increase in the life of the open-hearth roof in recent years is noteworthy. But a few years ago an average of 250 to 275 heats was considered fairly good. To-day an average of 400 to 500 heats is not uncommon, and single runs up to 800 to 900 heats are frequent. While by far the largest share of the credit for this marked change is unquestionably due to improved furnace design, methods of operation, and better brick-laying, we believe some credit is due to the better silica brick being made to-day.

In the by-product coke oven is seen the greatest development of recent years in the use of silica brick, displacing clay and quartzite brick completely above the oven floor and in certain portions beneath. It has developed surprising qualities in withstanding unavoidable changes in temperature and in meeting actual operating conditions. We have in heating furnaces one of the newer uses. It has in gas-fired pipe-welding furnaces proved a great economy and is adapted wherever there are no sudden changes of temperature. In the roof of large span and small rise the absence of shrinkage gives silica an advantage. As a whole, there are in the boiler arch too rapidly varying temperatures to render its use satisfactory, but where the boilers are gas fired, and sufficient care is exercised to prevent sudden changes of temperature, the worth of silica brick has been demonstrated.

There now remains the third division of our classification, namely, basic refractories. The introduction of the open-hearth process for making steel called for a refractory material for lining the bottoms and sides of furnaces that would resist the action of basic slag. The oxide of magnesium or magnesite, as it is called, was found best adapted for the purpose. Magnesite occurs in nature in two forms: the white or amorphous variety, and the crystalline form. In its natural state magnesite contains from 48 to 52 per cent. of carbonic acid gas, which must be driven off before the material is suitable for furnace work, and the difficulty of thoroughly calcining this white amorphous magnesite makes its use as a refractory impracticable. The crystalline form used by steelmakers is found in Austria, Hungary, and Sweden. The crude magnesite is burned in shaft or rotary kilns, crushed, sorted and sacked, ready for furnace bottoms or to be made into brick. An approximate analysis is as follows: Magnesia, 82 to 88 per cent. Lime, 3 to 4 per cent. Silica, 3 to 5 per cent. Iron peroxide, 5 to 7 per cent. A magnesite of this composition will flux sufficiently in a furnace to make a hard vitreous bottom, or if burned into brick will have a strong bond.

The process of manufacturing magnesite brick differs but little from that employed in making other brick. The temperature of burning, however, is very high, approximating 3,000° Fah. The major portion of magnesite and magnesite brick used in the iron and steel industry is for the bottoms of basic open-hearth furnaces and in the sidewalls extending above the slag line. This material is also widely used in the ports and blocks, and many furnaces are now being constructed where the end walls and uptakes are built of it. The bottom and sidewalls of electric furnaces of certain types are also of magnesite. Magnesite bricks are being generally adopted in iron and steel furnaces wherever basic slag is encountered.

Chrome ore, or chromite, is coming into general use in steel-making on account of its refractoriness and resistance to both acid and basic slags. It is a mineral that is practically neutral. It occurs widely distributed, being found in North America, Turkey, Greece, Japan, New Caledonia, Cuba, and Africa. In practice a chrome ore running from 40 to 50 per cent. chrome oxide and from 3 to 7 or 8 per cent. silica makes the best refractory. In the form of brick this material is used in open-hearth furnaces, soaking pits, and dolomite kilns. It is also ground and used as a patching and daubing mixture for repairing jambs, sidewalls, ports, and blocks of open-hearth furnaces. The process of making chrome brick is practically the same as in making magnesite brick.

In summarising this review of the use and development of refractories there are certain points that will bear emphasis, even at the expense of repetition. We note the frequent use of magnesia and chrome brick to resist basic slags, displacing a high-grade fireclay brick. We see silica brick displacing clay brick where the maximum refractoriness is required and where the variations in temperatures permit. We have a higher grade of fireclay brick displacing the lower. In these, as well as other instances that might be cited, this tendency is apparent, namely, the gradual substitution of the higher-grade refractories for the lower. The number and variety of difficult shapes is fast increasing. Brickwork is laid with greater accuracy. To-day less than half the clay or cement formerly used for laying is employed. As in other lines of manufacture, specifications are becoming more rigid. Firebrick manufacturers are now working under specifications that several years ago were considered impossible.

The brickmaker is somewhat limited in his efforts to develop his product by the fact that in the past 25 years no new beds of fireclay of a quality better than formerly used have been discovered. These clays all have their well-defined limits of refractoriness. He is therefore to meet new conditions confined to a mixture of known clays in various proportions, with suitable additions of calcined clay; to grinds of various degrees of fineness; to burns of varying degrees of hardness; and to special treatment of the clays. After a careful hand selection, any effort to increase the refractoriness by a further elimination of even a small percentage of impurities involves much rehandling in their weathering and washing, which is costly.

The future development of refractories will be interesting. The uses of silica are fast increasing; the field for basic refractories is widening, and it is probable that further refinement in the making of firebrick will justify the cost. This development presents problems for the iron and steel manufacturer, as well as the brickmaker, and we venture the opinion that with their continued co-operation much can yet be accomplished toward meeting the constant demands of the iron and steel industry in their efforts to increase their output.

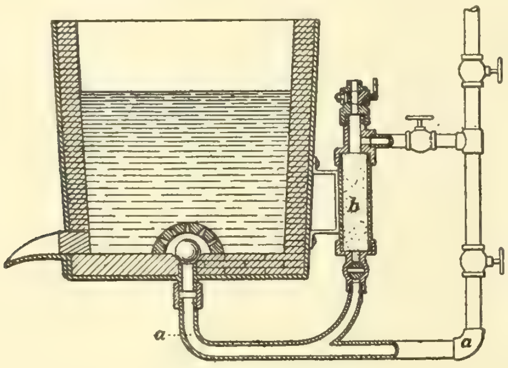
Fatal Flywheel Burst.—A workman was killed and several others were injured by fragments of a flywheel which burst on Monday last at the works of the British Westinghouse Electric and Manufacturing Company, at Trafford Park, Manchester. The wheel, which was 7ft. 6in. diam., weighed about three tons, and it was part of a generator set in the testing department. The flying fragments broke the fire sprinkler apparatus, and the greater part of the damage done in the works was due to water liberated in this way.

Scholarship in Naval Architecture.—The Royal Commissioners for the Exhibition of 1851, acting on the recommendation of the Council of the Institution of Naval Architects, have awarded the post-graduate Scholarship in Naval Architecture for 1913 to Mr. C. Frodsham Holt, of Liverpool, who recently obtained a first-class honours degree at Liverpool University. The scholarship is of the value of £200 per year, tenable for two years, and the holder proposes to carry out research work in present-day mercantile ship construction with a view to improvements in design based upon a study of longitudinal and transverse strength of ships and of the effect upon the strength of a ship of varying its length, breadth, and depth, and the spacing of its frames.

REMOVING SULPHUR FROM MOLTEN CAST IRON.

A PATENT has been granted to W. F. Prince, foundry superintendent, the Henry R. Worthington Company, Harrison, N.J., on a process for removing sulphur from molten cast iron. It is both novel and simple and also metallurgically interesting. The patentee claims to be able to reduce the sulphur content by 30 to 50 per cent. and has accomplished this in numerous instances. Sulphur is the *bête noir* of the iron foundryman. Any process by which the content can be kept down has special commercial and metallurgical value. Many castings have been lost because of the presence of defective spots of various sizes, attributed in many cases to kish, sand, or oxide. It occurred to Mr. Prince to have some of these spots analysed. He found them almost invariably high in sulphur, as also in manganese and silicon, while the normal iron of that part of the casting was lower in sulphur and manganese than the average for the casting. If the original surrounding normal iron contained silicon 2·50 per cent., sulphur 0·050 to 0·080 per cent., and manganese 0·70 to 0·90 per cent., then the composition of these spots was often found to approximate silicon 3·75 per cent., sulphur 0·40 to 0·60 per cent., and manganese 1 to 2 per cent. This was thought to indicate the presence of large amounts of sulphide of manganese, the high percentages of sulphur and manganese being decidedly abnormal and surprising.

The next step in the patentee's discovery was an attempt to reproduce, under commercial conditions, this unusual chemical compound or compounds. Success attended these efforts more



APPARATUS FOR TREATING MOLTEN IRON WITH AIR TO REMOVE SULPHUR.

easily than was at first expected, though Mr. Prince suspected the cause. He believed that these agglomerations of material, high in manganese and sulphur, did not exist in the original iron but that they were formed during pouring and usually in the mould itself. Being thus formed, the agglomerations floated along the walls of the mould until fastened there by the pressure and solidifying of the molten iron. The cause of the formation he ascribed to the ebullition of gas or steam through the iron, set free from the moulds or cores by the temperature and pressure of the liquid hot iron, a reaction taking place altogether too often. Acting on these surmises, Mr. Prince performed some experiments. He took a ladle holding 1,000lbs., and to the bottom, through a small hole, attached a pipe with a hole $\frac{1}{16}$in. diam. connected to an air system of 90lbs. pressure. Into this ladle the metal was tapped from the cupola. In each experiment at the end of 10 to 20 minutes of the gentle ebullition caused by the air a scum or slag was floating on top. Analyses of this slag showed it to be a compound entirely similar in composition to those forming the defects in castings. The results of eight different experiments of this nature are shown in the accompanying table.

These trials were so successful that Mr Prince experimented with different irons under different conditions with equally satisfactory results; so much so that a large tank was installed, equipped with the same convenient air connections. Castings made from iron thus treated showed a reduction of 25 to 50 per cent. in the sulphur contents, and in each case the iron was clean, sound, and easily machined. The physical properties also had not been sacrificed. While exhaustive tests have not been made to determine just how much sulphur can be eliminated, it is the opinion of Mr. Prince that it all depends on the amount of manganese present or added. In the hundreds of tests made the results, it is stated, have always been of the same sort. In each case the high sulphur has been lowered decidedly, passing off into the newly formed slag. The original iron has lost some of its manganese, but this can be avoided by adding powdered ferro-manganese to the stream of air. Other alloys, as well as carbon, for increasing the temperature, can be injected also.

The apparatus used and patented by Mr. Prince is shown in the illustration. Ordinary compressed air is admitted through the pipe *a* into the bottom of the ladle. The cylinder *b* is used for holding the powdered alloys that it may be desired to inject into the metal with the air. The entire mechanism is attached to the ladle so that the reaction can take place as soon as the metal strikes the ladle and while it is being transported some distance to the moulds. The reaction which it is claimed takes place as the "air, gas, or steam or other equivalent" comes into contact with the molten metal is that it oxidises the manganese, creating manganese oxide, which, owing to its affinity, unites with the sulphur to produce a slag which rises to the top of the ladle or reservoir, where it may be skimmed off. During this operation a small quantity of the manganese unites chemically with the sulphur to form manganese sulphide, which rises to the top after it is formed by the agitation produced by the oxidising agent.

TABLE OF EXPERIMENTS.

	Silicon. per cent.	Sulphur. per cent.	Manganese. per cent.
Experiment 1.			
Molten iron	2·55	0·051	0·72
Treated	2·53	0·035	0·52
Slag formed on top	3·65	0·429	2·16
Experiment 2.			
Molten iron	—	0·099	0·46
Treated 2½ min.	—	0·099	0·49
Treated 4½ min.	—	0·099	0·45
Treated 5½ min.	—	0·096	0·45
Treated 7½ min.	—	0·092	0·41
Treated 9½ min.	—	0·090	0·42
Treated 18 min.	—	0·065	0·31
Experiment 3.			
Molten iron	2·10	0·096	0·42
Treated 2½ min.	—	0·085	0·39
Experiment 4.			
Molten iron	—	0·095	—
Treated	—	0·075	—
Experiment 5.			
Molten iron	2·25	0·103	0·57
Treated	2·18	0·079	0·42
Treated	—	0·071	0·36
Slag formed on top	—	0·570	1·12
Experiment 6.			
Molten iron	—	0·074	—
Treated, first part	—	0·042	—
Treated, last part	—	0·033	—
Experiment 7.			
Molten iron	—	0·078	—
Treated, first part	—	0·042	—
Treated, last part	—	0·033	—
Experiment 8.			
Molten iron	—	0·070	—
Treated	—	0·056	—

The disposition of high sulphur iron with its consequent high combined carbon is always attended with difficulties. In quantities it is practically non-usable, for remelting. But Mr. Prince has found some surprising results from an application of his process to such iron. A quantity of high-sulphur borings was melted in the cupola, tapped into an experimental ladle, and treated. The iron that was produced was a high-grade soft iron having all the properties of a regular foundry iron. The analyses before and after treating were as follows:—

	Untreated, per cent.	Treated, per cent.
Silicon	1·02	2·05
Sulphur	0·129	0·089
Phosphorus	0·69	0·66
Manganese	0·36	0·44
Total carbon	2·36	2·43
Graphitic carbon	0·00	2·01
Combined carbon	2·36	0·42

In this experiment the sulphur is reduced 30 per cent. and the carbon has been nearly all changed to graphitic. Both ferro-silicon and ferromanganese were added during treating. It is believed that this opens up great possibilities, for it is claimed that not only can such impure iron be reclaimed but that even other irons high in sulphur can be used.

When application was made for the patent, the objection was at first made that it was an infringement of the Bessemer process. In the latter, however, the temperature increases greatly, due to the oxidation of the carbon and the silicon by the air blast; in the new process there is a gradual decrease in the temperature of the molten metal, inasmuch as there is no oxidation of the carbon or silicon, or practically none. It is claimed that the method can be used in connection with blast-furnace work, making pig iron in the usual way, drawing it into a receiver or ladle, treating it as above described, and then casting it into pigs, and that it is capable of use in all iron or steel foundries. It has been found of great advantage by the patentee in making large cylinders and pipe and heavy machine castings, increasing the factor of safety by preventing the formation of kish, &c., in the mould.—" The Iron Age."

THE ELECTRIC FURNACE IN THE STEEL FOUNDRY.*

BY ERNEST P. HUMBERT.

MUCH has been written about the electric furnace and its use in steel making, indicating the wide interest that steel men are taking in this new type. A better proof is the fact that over 100 electric furnaces are making steel in Europe and in America, these being of different types and sizes ranging from 1,000lbs. to 25 tons. I will try to show you the general advantage of the electric furnace for the making of steel castings. The requirements an ideal furnace would have to meet in a steel foundry are:

(1.) The making of a steel of the best quality; that is, a steel low in sulphur and phosphorus, as it is well known that these impurities affect the physical quality of steel—a steel which when cast will not show any blow holes, or a steel completely deoxidised. We have nowadays scientific and accurate ways of testing the quality of steel; we have the chemical analysis which will show us the quantity of the different elements which compose steel. It is only recently that the microscope has given us the possibility of knowing more about the structure of steel. It has shown that steel of good analysis—a steel low in impurities, such as sulphur and phosphorus—contains other impurities which were not revealed by chemical analysis. These impurities are oxides, silicates and manganese sulphide, and they occur during the making of steel. Part of these impurities stay in suspension in the metal, and being in particles of very small volume, they are not detected by the naked eye. It is easy to understand that the presence of these impurities diminishes the physical strength of the metal, and physical tests prove this without a doubt.

(2.) The second requirement an ideal furnace has to meet is the possibility of obtaining the metal at a very high temperature without injuring the quality of the steel. It is very important in a steel foundry to have the metal at a very high temperature, as it has to remain in the ladle sometimes for many minutes, and when castings of small size are to be made the chilling effect of the sand has to be taken into consideration.

(3.) The third requirement for an ideal furnace is that it be entirely adaptable to the demands of the foundry, namely: One that can be stopped and started at will without having to use fuel during the stoppage or the incurring of extra heavy expense; a furnace in which the heat can be kept for a certain length of time without a change in the composition of the steel; a furnace from which part of the heat can be removed at a time; a furnace in which steels of different qualities and analyses can be made from the same heat.

(4.) Finally, an ideal furnace will have to meet all of these requirements and make steel at a reasonable price.

Let us examine each type of furnace which is used in steel foundries, and determine whether any one meets the requirements which we have set for the ideal type. Four types of furnaces are used: the converter, the open hearth, the crucible and the electric furnace. These furnaces may be divided into two classes: the oxidising furnaces in which the heat applied has an oxidising effect on the charge, and which includes the converter and the open hearth, and the non-oxidising furnaces, in which, as the name indicates, the heat has no oxidising effect on the charge, and which include the crucible and electric furnace.

The Bessemer Converter.—If we consider the first requirement, which is the making of steel of the best quality, we find that the Bessemer converter does not meet it. There is no possibility of refining the metal. We are bound to have in the finished product the same quantity of sulphur and phosphorus which is in the pig; in fact, we find more sulphur and phosphorus in the steel, due to the increasing of the weight of the metal, and especially to the absorption of sulphur from the coke used for the melting of the pig iron in the cupola. If we take into consideration the second class of impurities which have been revealed to us by the microscope—oxides, silicates and manganese sulphide—it is obvious that with the Bessemer converter we have the greatest probability of finding these impurities in the metal. They are a by-product of the process. As no desulphurisation takes place, the sulphur in the metal will unite with the manganese which is added after the metal is blown and form manganese sulphide.

In the Bessemer converter steel can be made at a very high temperature, and it seems that the second requirement for the ideal furnace can be met. The heat is derived from the oxidation of the silicon. The only means by which the temperature can be raised is to increase the quantity of silicon in the pig iron or charge some ferro-silicon in the converter. One molecule of silicon unites with two molecules of oxygen to make one molecule of silica or silicon oxide. It is evident that we have the possibility of making very hot metal, but a certain amount of oxides, produced during the blowing, stays in the metal, and the presence of these impurities decreases the physical quality of the metal. If we increase the quantity of silicon we produce more silica, and the chance of having more of these impurities left in the castings increases proportionately. The conclusion is that although it is possible to produce in the converter steel at a high temperature, the physical qualities of the castings are diminished in so doing.

The first part of the third requirement of an ideal furnace is met by the converter. It can be shut down after the heat is made, and when another heat is required the furnace is heated with oil or coke, and after a short time is at a temperature high enough to take a charge of liquid pig. The great adaptability of the small converter to foundry requirements has been one of the reasons for its popularity with foundrymen. Unless a high percentage of silicon is used, which is objectionable, when the heat is blown it has to be poured, and it is impossible to make different sorts of steel with the same heat. The Bessemer converter meets only part of the third requirement of an ideal furnace. As to the fourth requirement, it is possible to make steel in the Bessemer converter at a reasonable price. From my knowledge of different works using converters for foundry purposes, in Europe as well as in America, I may state that steel can be put in the ladle around £6 per ton. Of course, if steel very low in sulphur and phosphorus is required, high-grade pig has to be used, with additional expense.

The Open-Hearth Furnace.—The other type of the oxidising furnace is the open hearth. The heating and melting in this furnace are done by the flame which results from the oxidation of coal gas, oil or natural gas by preheated air. The flame is mainly composed of carbon dioxide, which has very strong oxidising properties. In the United States acid and basic open-hearth furnaces are used, and in the foundries the acid is generally preferred.

The open-hearth process does not meet the first requirement of an ideal furnace the making of steel of the best quality, low in sulphur and phosphorus and not containing oxides, silicates or manganese sulphide. Low sulphur and phosphorus can be obtained in the acid process if high grade scrap containing a very small amount of these impurities is charged, but the melting being done by an oxidising flame it is impossible to produce a metal completely free from oxide impurities. With the basic open hearth dephosphorisation can be accomplished, but it is found that more oxides are dis-

* Abstract of paper read before the Pittsburgh Foundrymen's Association, December 8th, 1913.

solved in the steel. As to sulphur, it is always present, mainly in the form of manganese sulphide, and if in quantities may be found in the castings in the form of round globules.

As far as the second requirement is concerned, it is practically impossible to obtain in the open hearth the very high temperature which is required for the pouring of small castings. It does not have the flexibility of the converter. The furnace cannot be stopped and started again without serious trouble in the linings, and it is better to keep the heat on if the furnace is stopped for only a short time, as during the night or for one day. The heat has to be poured when ready; it cannot be kept in the furnace without the chance of over-oxidation and damage to the lining. The entire heat has to be tapped at one time and the only way to make different kinds of steel is to put the additions in small ladles and to pour the metal into them from the main ladle. The third requirement is not met by this furnace.

The open-hearth furnace can make steel for casting purposes at a reasonable figure. This varies with local conditions, the size of the furnace, and the tonnage produced; but under ordinary circumstances I can safely say that it will be £1 per ton less than the converter cost.

The Crucible Furnace. In the second class of furnaces, the non-oxidising, the heat applied for the melting of the charge does not have any oxidising action on the stock. The crucible furnace is used in steel foundries making very small castings, and which require material of good physical qualities. This is one of the oldest processes of steel making, and it is used now practically as it was 100 years ago. The crucibles, which are made of graphite and clay, or clay alone, are filled with scrap cut into small pieces and with the necessary additions to give the percentage of the different elements wanted in the finished metal, a cover is put on the crucible and it is placed in the furnace. The heat is applied in the same way as in the case of the open-hearth furnace, and when the metal is in shape it is poured from the crucibles directly into the moulds.

This furnace makes steel of the best quality, but no refining can be done in the crucible. It is impossible to change the sulphur and phosphorus which were contained in the scrap, and if a steel low in sulphur and phosphorus is required, scrap low in these elements must be melted. No oxidation can take place during the melting of the charge, and if scrap free from oxides is used the metal at the end of the operation will not contain any.

The second requirement is met by the crucible furnace, for it is possible to get the metal to a high temperature and to pour small castings of very thin walls. The main reason why good results are obtained in pouring these small castings is that the metal is poured directly from the crucible into the mould without its having a chance to cool down, as when transferred from the melting place into the pouring ladle, as is the case with every other kind of furnace.

If a coke furnace is used the first part of the third requirement is met, as the furnace can be started and stopped at will and with no difficulty. But if a regenerative furnace is employed the same difficulties will be met as with the open-hearth furnace, and almost to the same extent. The steel can be kept in the crucible a certain time after it is ready to be tapped without change in its composition or in the quality of the steel, although the life of the crucible prevents the overdoing of this. As every crucible contains a maximum of 100lbs. it is obvious that in a 32-pot furnace, 32 different kinds of steel could be made.

Everyone knows that crucible steel is expensive steel, and the fourth requirement of an ideal furnace is not met by this kind of furnace.

The Electric Furnace.—Although the electric steel furnace has been in existence for over 12 years it is only in the last few years that steel foundries have installed it. Several types are now in use in European and American foundries. I do not intend to discuss any particular type here, but only the question whether the electric furnace meets the requirements of an ideal furnace. With it we have the possibility of working on cold scrap or on liquid metal which has been melted either in the Bessemer or open-hearth furnace. The first method is used when a small tonnage is required, the second when a large tonnage is desired.

In the electric furnace, steel of the best quality can be made, as well as in the crucible, but the difference is that with the electric furnace scrap of the cheapest quality can be used and the sulphur and phosphorus can be removed to traces if desired. As the heating in the electric furnace is furnished by electricity it does not in any way influence the charge, and it allows us to operate in any atmosphere, neutral or reducing. The finishing slag of the electric furnace can be made so that it possesses a reducing property by which it can destroy any oxides that may be present in the metal. This slag is called "white slag" from its colour. Therefore, the electric steel will not contain any oxides, which means that the castings will be free from blowholes and show a very fine structure. As the sulphur is kept very low, there will be but little likelihood of finding sulphide of manganese. The first requirement is completely met by the electric furnace.

The electric furnace affords the possibility of obtaining a temperature much higher than that obtainable by any system of gas heating. With an electric current 3,500° C. can be obtained, the only limit to the temperature of the steel being the melting point of the refractories. The heat can be regulated as wanted, and the man in charge knows exactly the quantity of heat he is giving his furnace by looking at the instrument that shows the quantity of current used. The increasing of the temperature does not affect the quality of the steel, as this heat does not produce any change in the elements of the metal. From this we can see that the second requirement is met by the electric furnace. It is the only furnace in which the heating can be regulated with full control, where the maximum of heat can be applied instantly, and where the metal can be kept in the furnace during any length of time without the slightest variation.

The electric furnace being a closed furnace with no draught or stack, it holds the heat better than any other kind of furnace. It is the practice of many foundries to work only during the day time, the furnace being shut down at night. After the last heat has been tapped, if the doors of the furnace are tightly closed, the melter, coming in the morning to charge his furnace, will find it at a red heat. There is no need of keeping any current on the furnace or of heating it in any way during the night, as the cooling is not sufficient to give any trouble with the lining and brickwork.

The electric steel furnace being of a tilting type, any amount of metal can be taken at any time, and as a neutral atmosphere exists in the furnace and a neutral slag on the metal, the same quality of steel can be kept at the same temperature for any length of time desired. In special cases it may be found economical to make different kinds of steel with the same heat, for instance, straight carbon steel and some alloy steel. This can be done easily with the electric furnace. When the heat is ready, the furnace is tilted, and a certain quantity of carbon steel is poured into the ladle, then the furnace is tilted back, and the alloys wanted are charged in. When these alloys are melted and the moulds ready to be filled either part or all of the heat is poured in one or several ladles. The electric furnace can adapt itself to any requirement of the foundry.

The electric furnace also meets the last requirement—the making of steel of the best quality at a reasonable figure. With scrap not above £3 per ton and power at about ½d. per kilowatt-hour, electric steel can be made in the ladle for about the same price as steel made in the converter. When the price of power is low, as in Canada and some parts of the United States, electric steel can be made as cheap as open-hearth steel.

From the foregoing our conclusion must be that the electric furnace opens up possibilities to the foundries for making steel castings as good in quality as those made in the crucible, for the same price as those made in the converter and in some cases as cheap as with the open hearth.

The Institution of Mechanical Engineers.—An ordinary general meeting will be held in the Meeting Hall of the Institution, on Friday evening, January 16th, at 8 o'clock. The nomination of officers for election at the annual general meeting on February 20th will take place, and a paper on "Commercial Tests of Internal-combustion Engines," by W. A. Tookey, will be read and discussed. The "Thomas Hawksley" Lecture, on "Water as a Mechanical Agent," by Mr. Edward B. Ellington, will be given by Mr. Ellington during the current month as follows: Thursday, January 22nd, at 7-30 p.m., in the Medical Theatre of the University, Edmund Street, Birmingham. Wednesday, January 28th, at 7-30 p.m., in the Philosophical Hall, Park Row, Leeds. Friday, January 30th, at 8-0 p.m., in the Engineering Theatre of the University, Liverpool. A meeting of the graduates will be held on Monday, January 12th, at 8-0 p.m.

WORM AND WHEEL DRIVES.*

BY E. J. LEES.

WHILE the worm and wheel have been used for drives more or less successfully for a good many years, numerous tests have been made which prove that if properly mounted, and all materials, lubrication, &c., are as nearly correct as possible, an efficiency of 93 per cent. is possible, and some claims are made for even higher than this. In view of this it seems best not to go into the same paths of investigation any further than necessary, but to bring out if possible other vital points which are incidental, not only in the design, but in the manufacture.

At the Ingersoll Milling Machine Company's plant at Rockford, Ill., worms and wheels have been successfully used with dimensions as follows: The worm is 5½in. outside diam., 1¼in. circular pitch, 4 threads, 5in. lead, angle of 18° 26′, pressure angle 14½°, the depth of tooth conforming to the normal pitch, which is 1·186in., making the whole depth of tooth about ⅞in. The wheels have 50 teeth and some are made of bronze of the following analysis: Tin, 12·52; lead, 2·205; copper, 84·00; zinc, 1·24; phosphorus, 0·035. These worms of steel and wheels of bronze have been driving the horizontal cutter spindles of a large milling machine in the plant for the last 14 years without being replaced. One of the steel worms and a cast-iron worm wheel have been operating a large screw press for broaching and inserting teeth in the cutters which they manufacture. The pulley on the worm is 18in. diam. and has a 10in. driving belt. This drive has been in continuous use 17 years and the worm wheel seems to be in good shape yet.

From the above it is reasonable to assume that a worm with a thread angle from 17° to 43° will be successful, but there is one feature that must be taken into consideration, and this is the pressure angle of the thread. As the number of threads used in the worm is increased to get more lead and therefore more angle of thread, the pressure angle of the tooth should also be increased. If this is not done, the peculiar warped nature of the worm will not allow very much of the wheel to intersect with its teeth and will undercut them with a consequent loss of surface contact, which contact should be as great as possible.

Consider a blank with rings on it, then a thread; now add other threads, and the angle of thread will gradually increase until at a maximum we have a spur pinion, threads or teeth having changed 90° and at either extreme, it is very apparent that there will be no efficiency in a line parallel with the axis; and in regard to tooth contact it is clear that as the threads increase the action between the worm and wheel will be less until at the extreme or spur pinion all the teeth would be cut away in the wheel. Because the action between the worm and wheel teeth is largely sliding, it stands to reason that the area of contact in these teeth is governed to a large extent by the ratio, which is also controlled by the number of threads in the worm. And if an efficient angle is used the width of face of the wheel must be narrower as the angle increases; this statement is made assuming the wheel to conform to the worm and be made by the process known as hobbing.

If the face is made too wide the hob will cut away the ends of the teeth on the wheel to a point, but the greater pressure angle will eliminate this to some extent and allow more width and therefore more surface contact. To my mind the correct surface contact of the teeth in a worm and wheel is a most vital point, and a correct design may be spoiled by incorrect contact of the teeth, due to any factor in their manufacture and assembly.

In gearing in general, eccentricity is one of the great sources of trouble; this must be guarded against in making the worm, the wheel, and especially the hob. The worm wheel must not only run true on its pitch diameter, but must be bored perfectly true and not run out sideways. Designers may differ as to the form of tooth to use, but regardless of this whatever form is used, the best results will be obtained by making the hob in identically the same manner as the worm is going to be made; that is, as far as the tooth form is concerned. After this outline is obtained, of course, the hob may be relieved, but the relieving tool should be made to conform to the thread as made on the worm, working to the normal section. I mention this because so many hobs are ordered from a cutter maker who makes a relieving tool for a lathe according to his own ideas, and at the same time some shop is producing worms with threads that may or may not mesh correctly with a wheel cut with a hob. The above is all on the basis of trying to obtain the maximum efficiency and does not apply to very light loads and intermittent action.

As stated before, the action of a worm and wheel when transmitting is largely a sliding contact, and for all good sliding surfaces used in machine tool construction, the two surfaces are scraped together, and as a rule have a liberal area. The worm and wheel, on the contrary, are subjected to extreme pressure and are very seldom scraped together. If the cost of production will allow this, it is a very good plan to make the worm as perfect as possible in regard to concentricity and uniformity of teeth in size and indexing, with a very smooth surface after hardening, which even if ground should then be polished. Then mate the worm and wheel together in a fixture that will allow of centre adjustment, and scrape the bronze wheel to conform to the worm, using the regular methods of red leading or bluing the thread of the worm to find the contact on the teeth of the wheel to be scraped. The above appears to be a refinement which will be very expensive, but when you stop to consider the cost of inspecting and grinding in and other precautions that are used in comparison, probably is not so extreme as at first may appear, for it has the advantage of being successful; is based on the contact with a worm whose outline can be defined, and if these worms are exact duplicates, is interchangeable, a thing that is an absolute impossibility by any method of lapping or grinding where two surfaces are allowed to change haphazard in the process.

The need of interchangeability of parts manufactured in the modern shops of to-day has been the cause of the development of manufacturing down to extreme limits, measuring and testing machines, and the education of mechanics who are capable of producing to these limits; so that to-day we find a machine so delicate and accurate that it will measure the balls used in a ball bearing down to fractions of a thousandth of an inch, and ball races being ground so accurately that all the balls may do their share of the work and therefore make the ball thrust a success, where formerly it was condemned on account of a ball crushing. This was to be expected, when you consider that the balls varied in diameter and were placed in supposedly parallel bearings so that when the large ball came to the tight side of the ball race it alone had to take all the thrust and either crushed or scored up the ball race. Now that balls are made uniform and double spherical seats are used for the races, this is all eliminated.

The question might consistently be asked at this point why the spherical seats of the machine work and the balls are accurate, and the answer is that the burden of accuracy is constantly changing and at the present time is up to the material used and the strenuous work the mechanism has to do will often create a flexibility that must be taken care of. This brings us to the shafts on which the worm and wheel are mounted and the ball bearings used here should be of the self-aligning type, as this will readily take care of alignment and flexibility.

It is very evident that the ball bearing is destined to be a most important factor in the success of the worm and wheel as a drive. That the friction between the teeth of worm and wheel is not as great as many writers believe was brought home to my mind the first time I saw the boom of a locomotive crane revolve the worm of the hoisting mechanism backward through the worm wheel.

Elevator manufacturers use the worm and wheel to a large extent, and to do away with a ball bearing thrust one has adopted a rather ingenious arrangement in which each motor drives a shaft upon which is securely dowelled a right-hand and a left-hand worm that mesh with two worm wheels, one mounted upon the drum shaft and the other upon the idler shaft. There are also bolted to the worm wheels two straight gears, which are larger than the worm wheels and mesh together. The motors are arranged to run in opposite directions, both running in for raising or out for lowering. In this way there is no side thrust on the drum bearings, and the usual end thrust, present with the ordinary arrangement of worm and worm wheel, is taken care of by the two worms mounted upon each driving shaft, the thrust of each worm

* Abstract of paper read before the Cleveland (U.S.A.) Engineering Society, December 2nd, 1913.

just balancing that of the other. In this way the thrusts and side strains are so nicely balanced that the item of friction, usually a heavy one in this type of gearing, is greatly reduced.

Some elevator manufacturers use an arrangement somewhat similar, but in place of the worm wheels with spur gears bolted at their side, use two large helical gears right and left hand meshing together. In the central part of each a slight throat has been hobbed to make a seat for two worms to mesh with right and left hand. At first glance it looks as though it would be a rather hard problem to make the two worms mesh correctly with the two helical gears, because the two worms are cut on the same shaft. But on further inspection it is perfectly clear that all that is necessary is to turn the worms around until the lead of the thread brings the teeth of the wheel opposite the space in the worm thread, an allowance being made in the over-all length of the shaft for adjustment. Of course the angle of the teeth in the helical gear must be the same angle as the thread of the worm, so that after the helical gears are cut they can be hobbed without the hob interfering with the teeth already cut and yet make a correct seat with which the worm may mesh.

In summing up I will say that from all indications the worm and wheel as a drive will become more popular and more successful when it is thoroughly understood that all the factors which enter into its design and manufacture must be carefully looked into. There is certainly no doubt that the manufacturers of machine tools are doing their part to make machines which, if handled properly, will produce down to limits of extreme accuracy. The ball bearings which are now on the market meet the requirements demanded of them. The measuring machines are capable of measuring down finer than required. So we might conclude by saying that with a good design and manufacture there is no reason why the worm and wheel as a drive should not be a success.

Melting Point of the Refractory Oxides.—The U.S. Bureau of Standards, of Washington, D.C., have recently determined the melting point of the refractory oxides. In making the determinations the greatest difficulties were found in avoiding smoke (which would give low temperature readings) and the prevention of the contamination of the oxide by the material used as a support. The magnesia was melted in graphite, the aluminium in graphite and in tungsten, the chromium oxide in tungsten, and the lime in tungsten. The results obtained were as follows:—

Melting Points.

	Cen.		Fah.
Magnesium oxide (Magnesia)	2,800°	...	5,072°
Calcium oxide (Lime)	2,572°	...	4,661°
Aluminium oxide (Alumina)	2,050°	...	3,722°
Chromium oxide	1,990°	...	3,614°

The Aeroplane Engine.—A paper on aero engines was recently read by Mr. Granville E. Bradshaw, in the Engineers' and Shipbuilders' Institute, Glasgow. There was, he remarked, probably no form of prime mover in existence that was more highly stressed or that had a more strenuous life than the aero engine, and there was undoubtedly no engine that had greater claims on reliability. These facts at once suggested that the aero engine required greater accuracy of design, wider knowledge of the properties of the materials available for the construction of such engines, and the highest possible workmanship that could be obtained. It had been said that the modern aeroplane, although not by any means perfect, had already reached the stage of efficiency, so that extreme lightness of the power plant was no longer necessary to the evolution of the successful flying machine. This form of argument invariably came from those who had very little, if any, practical experience in aeroplane design, construction, or piloting. The aeroplane manufacturer's cry for the extremely light engine was probably greater to-day than it had ever been in the history of aviation. The first essential feature—namely, that an aeroplane should climb quickly depended almost entirely on the weight efficiency of the engine. Another essential—that it should have a combination of fast and slow flying speeds—was one of paramount importance, and one that aeroplane constructors were paying probably the greatest amount of attention to. The capabilities of a machine to fly slowly as well as fast depended almost entirely on the adoption of an extremely light and powerful engine.

JUNKERS' COAL CALORIMETER.

A METHOD of measuring the heating value of fuels, and a calorimeter for carrying out this method, which enables the calorific value of fuels to be determined with sufficient accuracy in such a simple manner that the apparatus can be operated by any intelligent workman, has recently been patented by Prof. Hugo Junkers, of Frankenburg, Bismarckstrasse, Aachen, Germany. The

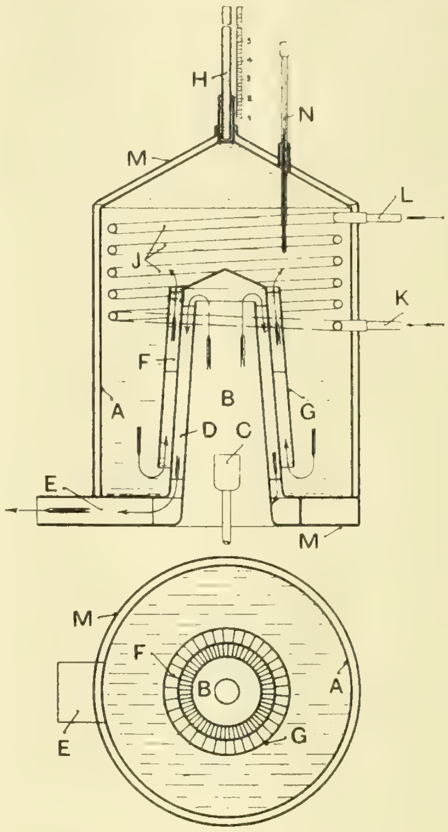


FIG. 1.—JUNKERS' COAL CALORIMETER.

method consists in using a calorimetric vessel filled with a definite quantity of liquid and allowing the hot gases given off during the combustion of the fuel to flow past heating surfaces which transmit the heat of the gases completely to the liquid contained in the calorimeter. The measurement of the heat, which when divided by the weight of fuel consumed gives the heating value sought, is performed by means of a special measuring device which is attached to the calorimeter and measures the increase in volume sustained by the liquid in consequence of the heating of same. In order that this increase in volume may bear a constant ratio to the amount of heat taken up by the liquid, which ratio, used as a multiplier, gives this amount of heat, use is made of such a liquid as possesses a coefficient of expansion which is independent of the temperature and remains constant within the limits of temperature coming under consideration. According to the researches of Prof. Junkers, petroleum is admirably adapted for carrying out the method, since its coefficient of expansion is constant at all the temperatures coming under consideration. The determination of the heating value is performed in an extremely simple manner by reading off the height of the liquid in the measuring tube of the calorimeter before and after the experiment, multiplying the difference by a constant and dividing the product by the amount of fuel consumed. The only correction needed in any event would be for the exchange of heat with the environment, and this could be determined in a very simple manner, but it has been found that this correction may be neglected if the quantity of liquid contained in the apparatus is so large in relation to the amount of fuel consumed that the liquid is only slightly heated by the combustion. In order to keep the difference in temperature between the liquid and the room as small as possible the liquid can be adjusted to a desired temperature before each experiment, by means of a special device, when it is not desired to wait for the very long time necessary, in the case of well-insulated apparatus, for the temperature to equalise naturally.

Two examples of the device are shown in Figs. 1 and 2. In

Fig. 1, A is the calorimeter vessel containing the measuring liquid; B the combustion shaft, in which the hot gases liberated by the combustion of the fuel in the burner, C, ascend in order to pass downward again through the heating passages D and escape through the exhaust outlet E. The combustion shaft B and heating passages are provided with heat exchanging devices which ensure complete transmission of the generated heat to the measuring liquid. The heat is taken up from the gases by gills arranged in the heating passage D and is given off to the measuring liquid mainly through gills F projecting into that liquid. A more active circulation of the liquid, and therefore an improved transmission of heat to the same, are obtained by means of the jacket G which surrounds the gills. A glass tube H fitted with a scale and mounted on the top of the apparatus, is provided for measuring the increase in the volume of the measuring liquid. Special heat exchanging devices are provided for adjusting the initial temperature of the measuring liquid. For this purpose there is provided a coiled tube J terminating in connections K and L through which tube a cooling or heating medium is passed as required. The actual calorimeter vessel A is surrounded by an insulating jacket M to prevent radiation of heat.

Fig. 2 illustrates a modification of the apparatus in which another arrangement is adopted for transmitting the heat of the gases of combustion to the measuring liquid. Here the exchange of heat is effected by heating tubes T communicating with the combustion passage B and surrounded by the measuring liquid. The gases of combustion passing from above downward through these heating tubes, give up the whole of their heat to the measuring liquid surrounding the tubes T. For measuring the expansion of the liquid, this apparatus is provided with an elastic membrane P the movement of which is transmitted, by means of the pinion gear Q, to the pointer R, the position of which can be read off on the scale S. In place of the ascending tube shown in Fig. 1 the apparatus shown in Fig. 2 is provided with a cock O which is closed when the apparatus has been filled, and prevents air from entering and the liquid from escaping.

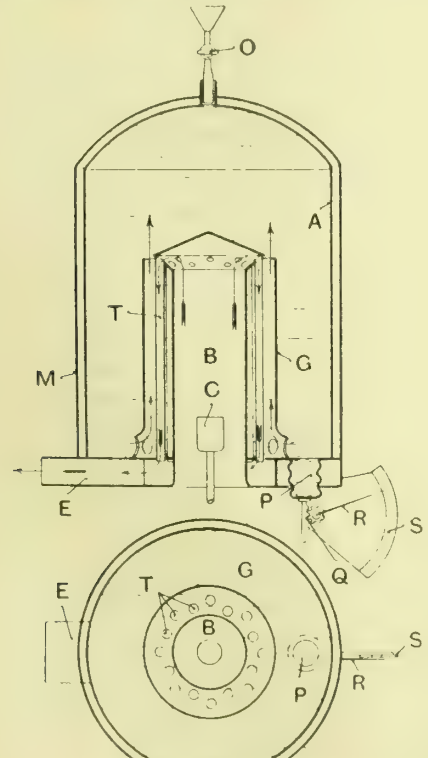


FIG. 2.—JUNKERS' COAL CALORIMETER.

The calorimeters must, in all cases, be made in such a way that no air bubbles, which would impair the accuracy of the results, can adhere in any part of the chamber containing the liquid. This result can be attained for example by the conical or domed shape given to the top of the measuring vessel in the examples shown. One and the same apparatus may be used for the calorimetric examination of solid, liquid and gaseous fuels, all that is necessary being to provide a burner suitable for the kind of fuel to be examined in each case.

THE BRITISH COAL INDUSTRY.

MR. WALTER HARGREAVES, in his presidential address to the Midland Institute of Mining, Civil, and Mechanical Engineers recently held at Leeds, said that the coal industry had enjoyed a remarkable spell of prosperity, despite detrimental influence and the subsidence of the general trade boom, which now was showing signs of coming to a premature end. The cost of production had been greatly increased by recent industrial legislation, by large advances in prices of every kind of stores, and by the advances in miners' wages, which were never so high as to-day, and which absorbed by far the greater part of the revenue arising from coal mining operations. The higher wages earned by miners had undoubtedly inclined them to work shorter time, and this inclination had been encouraged in many districts by the wrongful interpretation of a rule in the Minimum Wage Act, by which a workman who attends 80 per cent. of the days the mine worked in any week did not forfeit his right to the benefit of the Act.

During the past year the coal industry had probably been operating at not more than 75 per cent. of its full productive capacity, and that in the same period the cost per ton of coal had increased more rapidly than ever before known. The boom in trade, with a consequent advance in selling price, had for the moment submerged the fact of this greatly-increased cost of production, but much of this increase would be found to be permanent. If costs of production were reflected in selling prices of coal—and surely they were—then we might say that, despite all the progress which had been made in the scientific mining of coal during the period in question, the cost of production had gone up over 100 per cent., and this, he believed, was borne out in actual practice.

In reviewing the steps taken towards greater safety, Mr. Hargreaves said so long as they had mines they would have gas and coal-dust, and for the purpose of working the mines they must use artificial lights. He believed they had entered on a new era in the lighting of the working places of the mines with the electric lamp, and he outlined other provisions against accidents, but it was undoubtedly to the workman himself they must look if they were to see the mortality tables further improved. Official figures showed there had been a steady decrease in the loss of life per 1,000 men employed, the rate for the five years ending 1910 being 1·116 per 1,000, thus reaching the low-water mark. The disasters of this year would doubtless raise the average again, but it was, of course, only by taking a comparatively long period of years that the progress made could be accurately gauged. With regard to the general healthiness of the worker, coal-mining, he said, was one of the healthiest occupations upon which a workman could enter.

There was no disguising the fact that they were suffering from a plethora of legislation. The Workmen's Compensation Act and the National Insurance Act had given rise to a serious amount of malingering—a mean and disgraceful practice which was always difficult and sometimes impossible to detect. Discussing the Minimum Wage Act, Mr. Hargreaves said: It was law, of course, and we had to make the best of it, but there could be no doubt that it had operated to the detriment of many collieries, while the miners were no more contented than they were before the great strike of 1912, which brought it about. The men were dissatisfied with most of the awards under it, and the Miners' Federation of Great Britain, judging by its Scarborough programme, regarded it as only an earnest of what was to come. What the Act was costing the coal industry at the present time it was difficult to ascertain with any amount of precision, but it was certain that the country generally still regarded the principle with misgiving. Already they had rules and regulations innumerable—so many indeed that the unhappy colliery manager in his efforts to grasp them all might well fail to get a real grip of the principle of some. There seemed to be great danger of the industry being bound in red-tape fetters, if it was not in that condition already.

During the year a good deal had been heard concerning oil fuel, and special prominence was given to the question by the announcement of the First Lord of the Admiralty of the

decision to build not only small but large warships in which oil would take the place of coal as a motive power. The Welsh coalfield would be most affected, although a considerable quantity of north country coal was used for naval purposes. It was computed that the Admiralty bought about 2,000,000 tons per annum of all sorts, and might consequently be looked upon as good customers. In the case of warships speed was the dominant factor, and cost was of no account; but in the case of "tramp" steamers, and, in fact, of all users of power on either sea or land, cost was the principal consideration. But if there was a general move in the direction of oil, where was the oil to come from? The world's production of coal was 1,200,000,000 tons per annum, while the world's production of oil was 50,000,000, and if any great increase in the demand for oil fuel took place, it would be very soon accompanied by advances in prices, on the principle that an article was worth just what it would fetch in the open market. He took it, therefore, that the coal industry in our day, at all events, need have no serious alarm for its future as threatened by oil. Since at a conservative estimate they had another 400 years to run before exhaustion came in sight, he did not think that they need be much troubled on that score.

It was his belief that the coal industry of this country and the mining engineer still had a great future before them, although the day of cheap coal, as the term was understood 30 years ago, had gone never to return. There had been great changes in the past, and they must look for further great changes in the future, particularly in regard to the by-product industry. It had grown by leaps and bounds of recent years, and was now a valued and trusted auxiliary of the coal-owner. It might be that the British coalfields would come to be regarded as oilfields rather than coalfields, that the by-products would be considered as of primary importance, and the coal itself valued mainly as the basis of them. Already attempts had been made to induce the householder to substitute coke for coal on the domestic hearth, and the gas companies were endeavouring to promote its use under boilers in London and elsewhere.

CORRESPONDENCE.

"Thermo-electric," "Thermo-pneumatic," and "Internal-combustion" Railway Locomotives.

To the Editor of "The Mechanical Engineer."

Sir,—I note you refer to my recent letter in the "Times' Engineering Supplement" concerning the "Paragon" and the "Standard" types of "thermo-electric" locomotives. May I add that I have chosen the name "thermo-electric" as being in my opinion the right name to use in the case of using electric transmission from the internal-combustion engine to the axles. Recent tests in Germany show that fairly good results have been obtained, but not what locomotive men call proper commercial results, from a "thermo-pneumatic" railway locomotive. I believe that this locomotive was described in one of your previous issues. It starts and runs up to about six miles per hour as a "thermo-pneumatic" locomotive, and then operates as an "internal-combustion" locomotive. It appears to me a very unsatisfactory design, because it is well known that it is at starting and during the period of acceleration that generally most power is required. Yet in this German design of "thermo-pneumatic" locomotive (it is not a real internal-combustion locomotive), we find that for starting and acceleration of the train up to about six miles per hour we have the main engines operating compressed-air motors supplied with energy by a 250 h.p. air pump, which is driven by a separately-installed internal-combustion engine. Not only is there no relative gear ratio between this pump and the piston area on the main engines, but the locomotive is "time" limited as regards power, for the power transmission efficiency, when operating under air pressure alone, cannot be much higher than, say, 50 to 60 per cent., especially when taking into account the waste that takes place in putting air under very high compression in storage bottles for expansion in power production; further, the high pressure air essential for providing high torque for starting and acceleration being used in the relatively small volume cylinders essential in the main motors, when operating under actual fuel conditions, requires the air pressure kept on for most of the stroke, as in the case of a steam locomotive, to get a high mean effective pressure practically no expansion, with its economy, is possible, and with the exception of the time at which the locomotive is operating on oil fuel direct, such as, for instance, when travelling above six miles per hour, I fail to see where the economy can possibly be shown as compared with a superheated and possibly compounded steam railway locomotive. The design shows only two axles are driving axles, and this is, I consider, hardly progressive, compared with our electrical friends, who have undoubtedly proved that a tractive effort of something like one-third of the total weight of the electric locomotive is practical and at work, but no doubt this high efficiency is due to the extremely even and high starting and running torque which is delivered by the electric motors, which are usually fitted (as in my design "thermo-electric" locomotives) on all axles, in order that the total weight can be utilised for adhesion, so essential in these days of heavy haulage work, and especially in freight-train operation on mountain divisions. In my opinion it would have been much more efficient if the constructors of the "thermo-pneumatic" locomotive had used electrical power transmission from the auxiliary engine to all the axles, and then to have used the direct fuel after getting, say, their six miles per hour. They could, of course, have used both methods when the locomotive was travelling above the six miles per hour. I am certain that they would have got a much more rapid and easier acceleration than with the present method, with all its complicated operation. It is my opinion, and which opinion is based on a good deal of practical work, in the design and construction of self-contained and self-propelled vehicles, that the best "mechanical" as well as the best "commercial" job is the one which I have now in hand, in which the internal-combustion engine is always running at its maximum speed, thus using the fuel at the best economy, and for the purpose of starting and acceleration the total number of efficient power strokes of the engine is available, the increased gear ratio and increase in torque being obtained, by means of the induction motors, by change in the frequency in the supply (polyphase alternating current) and the pole ratio in the axle motors, with the most simple and rapid control, without the messing about with change of mixtures, as is essential in connection with the combined "thermo-pneumatic" locomotive.

The "Paragon" Locomotives.—These alternating-current "thermo-electric" locomotives are at present being designed for use on an important colonial railway, with squirrel-cage induction motors wound for two polarities or speeds on each of the three frequencies at which the generating plant supplies, thus, six efficient speeds are given in either direction at constant engine revolution speed, the prime mover being in this instance (although other types of engines are equally applicable) a Diesel type of "constant-pressure internal-combustion engine," using a fairly heavy residue oil. These squirrel-cage locomotives are very strong and simple, and are quite suitable for railways where grades are not too severe, and where separate locomotives can be used for slow-speed freight work, and with larger diameter wheels for passenger service at high speed. But in cases where it is desirable to use the same locomotives for both passenger and freight work, the design of the electrical plant as regards the axle motors and control gear is different. In the latter case, no less than 17 running speeds are given at constant engine speed, with three frequencies on the polyphase current supply, and arranging that both the motor stators and the rotors are supplied with equal or different frequency current, and in multiple series or parallel connection, and without using wasteful regulating resistances the above speeds are rapidly given and controlled from either end of the locomotive, just as easy to drive as a simple tramcar. In the case of the 2,000 h.p. locomotives referred to, in which double-acting gas engines are embodied, the gas used is a fixed gas made from extremely rough and heavy residue oil. It is an oil that could not be used direct in a Diesel engine, and has a specific gravity of

·950, the water in which does not exceed 2 per cent., the sulphur about 4 per cent., and the calorific value is about 19,000 B.T.U. per pound, which fuel costs 25s. per ton delivered on the spot, whereas an oil suitable for using in a Diesel cycle engine would cost about 60s. to 70s. per ton, quite apart from the fact that these double-acting six-cylinder gas engines require no flywheel, which is an advantage from many aspects. It was this question of fuel cost which really decided the matter as to the type of prime mover I proposed in this instance.

Real "Internal-combustion" Locomotives. In certain cases and for use anywhere, where ordinary steam locomotives are giving satisfactory mechanical duty, but where the great efficiency and consequent haulage fuel economy is desired, a real internal-combustion system for locomotives is embodied in my "Invicta" railway locomotives. In this case fuel and not compressed air is used for starting and accelerating trains, all wheels are driving wheels, single-acting cylinders are used, and although reasonable piston speeds are "actually" used, the method of operation gives the advantages of very high piston speeds (a point which will be appreciated by all designers of internal-combustion engines), the torque regulation is obtained by supply of air and fuel in variable quantities according to operating conditions, and the special cycle used is novel and embodied in my invention of 1912, in which the detrimental effect of altitude is overcome, insomuch that it becomes possible that these locomotives will pull as heavy trains at an altitude of 9,000ft. as they will on sea level, an engineering accomplishment of no mean order, especially when bearing in mind that approximately for every 328ft. rise an ordinary internal-combustion engine loses about 1 per cent. of its power. At the same time, cumbersome exhaust boxes are not used, nor are they wanted, because the expansion is taken practically down to the pressure of the atmosphere, and the exhaust is therefore practically silent, and the heat and pressure usually given as waste to the atmosphere is utilised in actual work. Recent tests have proved that with this cycle of operation more horse-power is obtained from a given amount of fuel than probably any other internal-combustion engine on the market to-day. It certainly is ideal for locomotive practice, and by reason of its higher thermal efficiency requires less amount of water for cooling purposes, which in certain cases of internal-combustion locomotive design, and with certain high atmospheric temperatures to be dealt with in hot climates is a material advantage from the cooling radiator point of view, in high temperature climates the disposal of the jacket heat losses is a problem of great difficulty which is faced by all internal-combustion locomotive designers, and this special cycle of internal combustion of fuel offers many practical advantages.

The "Standard" "Thermo-electric" Railway Locomotives.—These special-design locomotives have very important electro-mechanical features, but patent law does not permit me to say much at present, but your readers can believe me that, as machines for the production of tractive effort for railway or roadway train haulage work, they are the production of many years of practical experience, and that they will prove that the principle of "internal combustion" in the place of "external combustion" has come to stay.

I believe 1914 will see some radical changes in railway haulage work in the direction of the utilisation of the internal-combustion principles, which will benefit mankind in general —Yours respectfully,

WILLIAM P. DURTNALL,
Member Inst. Locomotive Engineers
London.

December 27th, 1913.

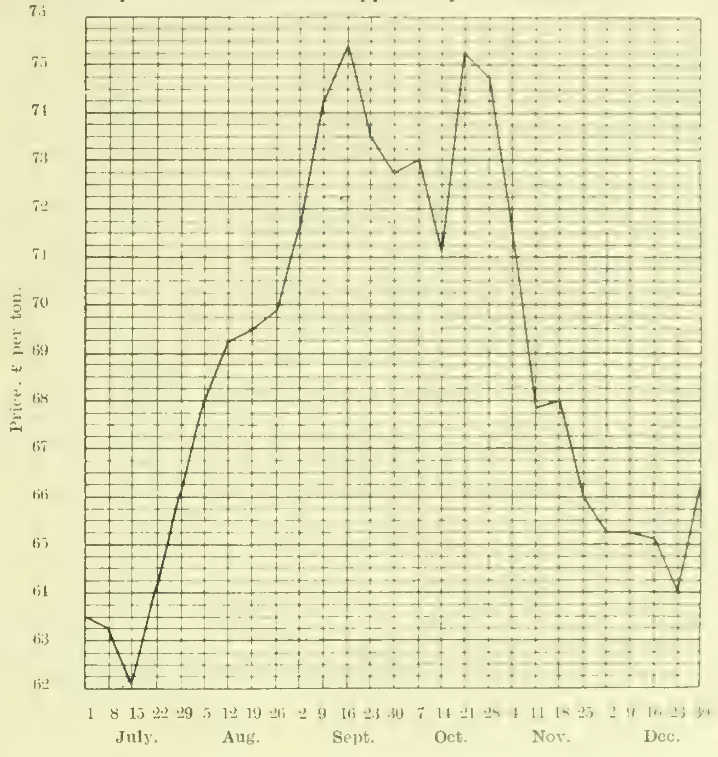
Lectures on Electricity Generating Stations.—In connection with the departments of electrical and mechanical engineering of the Battersea Polytechnic a course of advanced lectures on generating stations will be delivered by W. H. Patchell, M.I.C.E., M.I.E.E., on Mondays, January 19th, 26th, February 2nd, 9th, 16th, 1914, at 7-30 p.m. The lectures are intended for advanced students, and admission will be free, no tickets being required.

INDUSTRIAL AND TRADE NOTES.

Cumberland Iron-Trade Depression. Evidence of the deepening depression in the Cumberland hematite iron trade has been furnished by the damping down of the two furnaces which were in blast last week at the Distington Ironworks. This is the first time since the coal strike that both furnaces have been put off blast. A furnace is also to be damped down at the Combine's Solway Works at Maryport.

Oil for the Navy.—The Admiralty propose to erect oil fuel tanks at Blackness, on the Firth of Forth. Blackness, which is in the vicinity of the Rosyth naval base, and is within easy reach of practically all the refineries of the Scottish mineral oil companies. It is stated that the proposal is to connect the depôt with the refineries by means of pipe lines, thus enabling the oil to be pumped almost directly from the refineries into the oil tanks of the war vessels.

Prices per Ton of Standard Copper, July to December, 1913.



Shipbuilding in Canada.—Messrs. Yarrow & Co., of Scotstoun, have acquired a site at North Vancouver with the view to the establishment of a shipyard. Messrs. Yarrow hope to secure contracts for the construction of small warships for the Dominion Government, but the firm is acting entirely upon it own initiative, and is largely influenced by the conviction that the opening of the Panama Canal will give a tremendous impetus to the shipbuilding industry on the Pacific Coast.

Mather & Platt's Turbine Pump. We have received from Messrs. Mather & Platt, Ltd., Manchester, an interesting cardboard model illustrating the action of their well known turbine pump. Operation of the pump and the relation of the ports and blades are clearly shown, and by means of rotary scales it is possible, by setting one scale to the gallons and head per minute, to read on another the B.H.P. absorbed opposite the pump efficiency. To those using pumps of this kind, therefore, the model is interesting and useful.

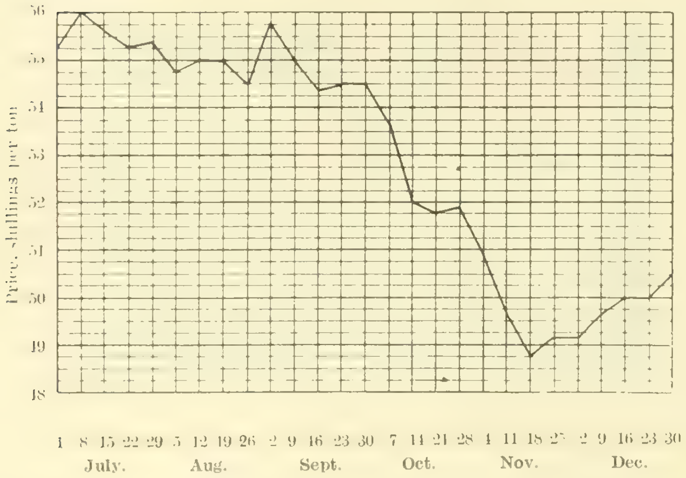
Successful Trailer Tramcars.—The experiment of running trailer cars on certain of the South London tramway routes has proved so successful that the London County Council is proposing to bring this method of transit into more general use. Application is being made to the Board of Trade for permission to run more trailer tramcars on the southern routes, and pending the receipt of the Government Department's consent, prices are being obtained for 150 trailer cars and also for the equipment with couplers of about 200 of the existing electric cars.

Railway Electrification in Lancashire.—The directors of the Lancashire and Yorkshire Railway Company have determined to electrify that portion of their railway which runs from Manchester, viâ Prestwich and Radcliffe, to Bury. The trains will be worked with direct current collected from a third rail, as on the Southport line. Experiments are also being made on the line between Bury and Holcombe Brook with a high tension direct current system.

in which the current is collected from an overhead wire, the equipment in this case having been supplied by Messrs. Dick, Kerr, and Company, of Preston.

Canada's Longest Tunnel. After fifteen months and four days of boring the preliminary bore of the Canadian Northern Tunnel from Model City under Mount Royal and into the heart of the City of Montreal has just been completed. The tunnel is the longest yet built in North America. It is some 16,668ft. in length. As at present finished it consists of an 8ft. by 12ft. heading com-

Prices per Ton of Cleveland Iron, July to December, 1913.

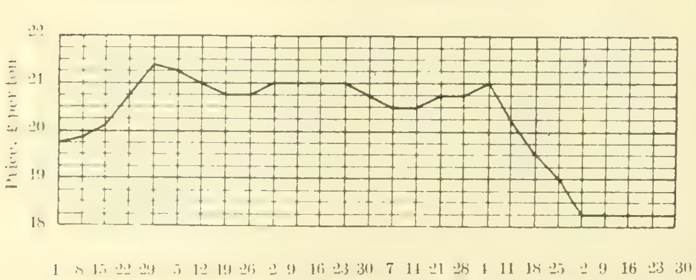


pleted the entire distance, with a very considerable amount of the total three miles already enlarged to the ultimate 22ft. by 30ft. size. The tunnel will be rapidly excavated to this size, and within 12 months will be completly finished and ready for the running of express trains.

Output of Coal in 1912.—Prof. R. A. S. Redmayne, Chief Inspector of Mines and Quarries, reports that the total value of the minerals raised in 1912 was £131,220,853, an increase of £6,641,540 as compared with 1911. The total output of coal was 260,416,338 tons, and the value £117,921,123, showing a decrease in the output of 11,175,561 tons, but an increase in value of £7,137,141 on the figures for 1911. The average price of coal was 9s. 0·68d. per ton in 1912, as compared with 8s. 1·79d. in 1911. The total quantity of coal exported was 85,842,905, as against 87,081,382 tons in 1911. The amount of coal remaining for home consumption was 174,573,433 tons, or 3·823 tons per head of the population.

British Orders for Germany.—The Press Association is officially informed that the Port of London Authority have placed contracts for three pairs of lock gates, a bascule bridge, a swing bridge, and a caisson for the dry dock in connection with the Royal Albert Dock extension (South) with two German firms. The order for the lock gates has been placed with the Gutehoffnungshutte Aktienverein fur Bergbau und Huttenbetrieb. The con-

Prices per Ton of English Lead, July to December, 1913.



tract for the bascule bridge, swing bridge, and caisson have been given to the Maschinenfabrik Augsburg-Nurnberg. These contracts were obtained in competition with British firms, and show a saving of nearly 26 per cent. on the lowest British tenders of £179,071.

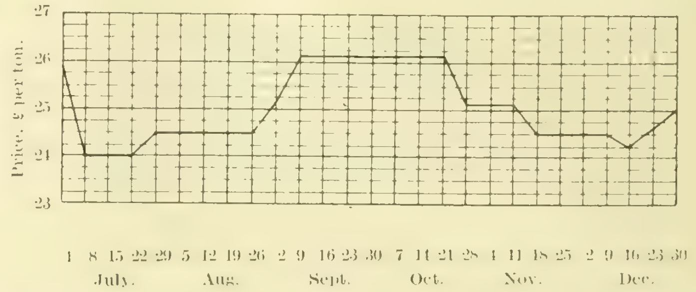
Scarcity of Pig-iron in Russia.—The scarcity of pig-iron in Russia is the subject of a dispatch from Mr. H. Cooke, His Majesty's Commercial Attaché for Russia. All branches of industry, he says, are reported to be suffering increasingly from the insufficient supplies which are available, as the demand is out of all proportion to the supply. In consequence of the deficiency of iron, orders for the construction of steamships, dredgers, &c., have to be placed abroad. A member of the Duma has declared that the only solution appears to lie in the authorisation for several years of the import of foreign iron at a reduced rate of Customs duty. A group of members of the Duma propose to confer with members of the Government, and in the near future to bring in a Bill for a reduction of the duties.

Personal.—Sir Frank Ree, general manager of the London and North-western Railway Company, who will retire early in the New Year, is to be succeeded by Mr. Guy Calthrop. He joined the London and North-western Railway Company in 1886 as a junior on the staff of the superintendent of the line. Some eight years later he was appointed superintendent at Crewe, and in 1901 he became assistant to Sir Frederick Harrison, then general manager. He became general superintendent of the Caledonian Company, and later general manager. Some idea of the business conducted by the London and North-western Railway Company may be gathered when it is stated that it has almost 2,000 miles of railway, over 3,000 locomotives, about 10,000 passenger coaches, 77,000 goods wagons, and 16 steamships.

Austrian State Railways.—The American Consul-General at Vienna states that the total railway mileage in Austria at the end of 1912 was 11,806 miles, of which 8,080 miles of track are the property of the State, 436 miles private-owned railways operated by the State, and 3,290 miles owned and operated by private parties. The capital invested in the Government-owned railways and private lines operated by the Government at the end of 1912, is estimated at about £228,000,000, an increase during the year of nearly £26,000,000. The regular income of the Government railways during the year was about £35,000,000. The cost of working was £25,600,000. The surplus for the year is computed at over £8,000,000, or about 3·93 per cent. on the invested capital.

Municipal Telephones for Hull.—The Hull Corporation has decided to purchase from the Post Office the telephone undertaking in the Hull area, at a price of £192,000. Hull had a Corporation telephone system in competition with the National Telephone Com-

Prices per Ton of Silesian Zinc, July to December, 1913.



pany, and will now be the only Corporation to run its own telephone undertaking. It was stated that the Postmaster-General had given the Corporation every consideration. The license will be for 21 years, and it is interesting to note that under the Corporation, subscribers will have the telephones at rates considerably cheaper than those offered by the Post Office.

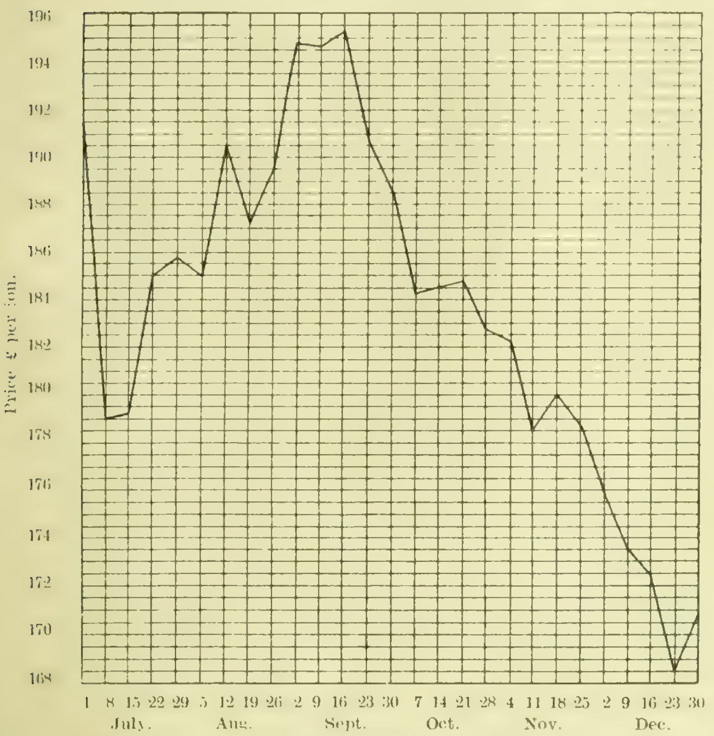
Proposed Extensions to Rotherham Corporation Electricity Works.—A striking report of the growth of the electric supply of the Rotherham Corporation works has been furnished by Mr. E. Cross, Borough Electrical Engineer. The works were opened in 1901, when 87,174 units were sold. The number for 1912-13 was 3,615,531, and the estimate for 1913-14 is 5,000,000 units. He adds that he has reason for stating that this progress will be greatly accelerated owing to the increased popularity of electric driving and a considerable increase in the cost of coal recently. He had already received enquiries for something like an equivalent of 1,000 h.p., and this it would be impossible for the department to cope with without increased plant. Reasons are given for extension, and he recommends the purchase of machinery and buildings at a cost of £15,956. Application will be made to the Local Government Board for sanction for the borrowing of the money required.

Diaries and Calendars.—We have received a number of calendars and diaries. Messrs. D. Bridge & Co., Ltd., of Castleton, Manchester, the well-known makers of friction clutches, rubber, and other special machinery, send us a handsome and convenient little diary for pocket use.—The United States Metallic Packing Company, Ltd., Bradford, Yorks., make a speciality of calendars with figures in relief. These are quite works of art in their way, and serve to materially relieve the drab walls of the ordinary office. The present issue is in no way behind its prede-

cessors, and portrays a figure of Canova's "Hebe." Messrs. W. H. Willcox & Co., Ltd., 38, Southwark Street, London, S.E., makers of engineers' fittings and supplies of all descriptions, ranging from large prime movers to oil cans, send us a useful wall calendar. We have also received similar types of calendars from the Baldwin Locomotive Works, of Philadelphia, Pa., U.S.A., Messrs. Nalder Bros. & Thompson, Ltd., Dalston Lane, London, and Messrs. Theodore Butler, Ltd., 149, Queen Victoria Street, London, E.C.

Amalgamation of Water-softening Plant Manufacturers.—An important combination of leading makers of water softeners in the United Kingdom is announced. Arrangements have, we are informed, been concluded under which the two concerns of Lassen & Hjort and Water Softeners, Ltd., will henceforth operate in the British Isles as a joint concern under the title of United Water Softeners, Ltd. Messrs. Lassen & Hjort are well known as the patentees of a system of softening water by means of lime and soda, whilst Messrs. Water Softeners, Ltd., are the proprietors of the recently introduced "Permutit" regenerative process. The management of the new company will be in precisely the same hands as was that of the two original concerns, and pending the acquisition of new and more commodious offices in which both staffs will be brought together under one roof, the business of the new company will be carried on at the existing offices of the two concerns jointly.

Prices per Ton of Block Tin, July to December, 1913.



Launch of a Large Oil-carrying Steamer.—On Saturday last week there was launched from the Wallsend Shipyard of Swan, Hunter, and Wigham Richardson, Ltd., the large oil carrying steamer, "San Lorenzo," built to the order of the Eagle Oil Transport Company, Ltd., of London. She has been designed to carry some 15,500 tons of oil, and is the last of three sister ships that Messrs. Swan, Hunter, & Wigham Richardson, Ltd., launched last year, and is the seventh built by them during 1912 and 1913 for the same owners. Like the "San Fraterno" and the "San Gregorio," the "San Lorenzo" is 541ft. long, with a breadth of 66½ft., built upon the Isherwood system of longitudinal framing. The quadruple expansion engines and boilers are being built by the Wallsend Slipway and Engineering Company, Ltd. The boilers are fitted with the Wallsend Howden patent apparatus for burning liquid fuel. The oil holds together with the oil cross bunker are divided into 26 compartments by transverse and longitudinal oil tight bulkheads.

Birmingham and its Industrial Advancement.—In his presidential address delivered before the Birmingham Association of Mechanical Engineers, Mr. A. Home Morton, in referring to the development of Birmingham and her trades, pointed out that, great though the efforts had been which had brought the city to her present greatness as a centre of industry and commerce, it would be a much greater task to ensure that she should keep the eminence gained. Birmingham could only maintain her present prestige by obtaining very much greater industrial efficiency throughout the city and district. He showed that the greatest drawback to the industrial advancement of the city and district lay in the out of date factories, the obsolete machinery, and old fashioned methods to be found in use on all sides. Every manufacturer could not build a brand new factory laid out and equipped on modern lines on a new site but practically the same effect could be obtained by reconstructing little by little, as time and money allowed, along a previously determined carefully thought out scheme of reconstruction for the whole factory or works. In this way the cost would be a little more but it would be spread over a number of years, and, perhaps, be met out of revenue. The cost would be no more than was frequently spent over the same time in making impulsive alterations which resulted only in patchwork in newer materials instead of a well laid out works and an improved asset. Something had already been done, and was being done, along these lines, but there were few districts, if any, in which there was so much scope for modernising works and factories on sound commercial lines as there was in and around Birmingham.

Suggested Mersey Tube.—A project for connecting Liverpool by means of wide subways under the Mersey with Birkenhead and Wallasey has been submitted to the Liverpool Tramways Committee by Mr. C. W. Mallins, the general manager. The new tunnel scheme may be said to be in two parts. To relieve the traffic along the two Pierhead routes—Church and James Streets and Dale and Water Streets—it is suggested that a tram subway be constructed to the landing stage from the triangular site between Dale Street, Manchester Street, and the Old Haymarket. Such an underground route would, no doubt, serve to divert traffic between the centre of the city and the Pierhead; but Mr. Mallins invites his committee, and through them the City Council and the authorities of the two Cheshire boroughs, to consider the feasibility of dealing with the port problem as a whole by continuing the tunnel under the Mersey to Birkenhead and Seacombe, with sufficient width of way to accommodate fast and slow vehicular traffic as well as pedestrians, and with approaches at convenient places. The cost of the undertaking is estimated at three millions sterling. Mr. Mallins estimates that his scheme would be on a paying basis with 45,000,000 passengers at 1d., and 1,000,000 vehicles at 6d. It will be seen, therefore, that in order to avoid a financial loss, practically the whole of the present traffic, both above and under the river, would have to be diverted to the new subway. The Tramways Committee expressed no opinion on the scheme, contenting themselves with formally receiving the report and resolving to present it to the City Council.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1912.

Process for the extraction of sulphur from iron pyrites. Hall. 20758.

Variable throttle valve. Ovenden. 21093.

Internal combustion engines. Gillespie. 21189.

Automatically operating temperature regulators for heaters, or coolers, humidifiers, and other devices. Weigert Sterne. 23758.

Process for the extraction of sulphur from metallic sulphides. Hall. 26595.

Motor cars. Nicholson. 28534.

Valves in internal combustion engines. Knight. 28693.

Valves of internal combustion engines. Elsensohn. 28778.

Process for removing water from peat. Browne. 28834.

Cooling of internal combustion engines. John I. Thornycroft and Co., and Thornycroft. 28843.

Vacuum brake apparatus for railway vehicles. Luard. 28969.

Spray carburetters. Terry & Terry. 28987.

Propeller applicable to aerial and nautical navigation. Filippi. 29170.

Solder. Wilkins, Wilkins, & Morris. 29239.

Gear cutting machines. Parsons, Carnegie, & Cook. 29380.

Process of separating mixed liquefied gases. Morrison. 29383.

Motor starting device. Cialente. 29486.

Alarm gauges for indicating the pressure of steam. Davies and Jones. 29500.

Steam condensing plants. Muller. 29578.

Chain pipe vises. Amborn. 29591.

Metal fire bridges for the furnaces of steam generators. Jones. 29657.

1913.

Process of and apparatus for the manufacture of welded tubes. Bachem. 54.

Apparatus for stoking furnaces. Williams & McPhee. 74.

Steam turbine. Coppus. 217.
Pumping apparatus. Wattles. 955.
Metal alloy. Monkhouse & Denton. 1819.
Steam traps. Davidson. 1955.
Wire drawing. British Thomson Houston Company. 2001.
Non conducting jackets for boilers. Hutsel. 2437.
Valves and valve-gear for internal-combustion engines. Huntington & Maltby. 2585.
Adjustable wrenches. Roberts. 2630.
Steam super heaters. Hutchinson & Maunsell. 3778.
Resilient wheels and pulleys. Doll & McClung. 4174.
Lifting devices. Smith & Osborn. 4237.
Chucks for rock drills. Newton. 4677.
Coal conveyers. Hyve. 4700.
Combustion chambers and vaporisers on internal-combustion engines. De Rusett. 5345.
Radiators for internal combustion engines. Goudard & Mennesson. 6440.
Power transmission gear. Wirtz. 7849.
Valves for air-compressors. Holman & Holman. 8050.
Nickel copper alloys. Douglass. 8331.
Feed-water heating installation for steam generators Buchmann and Weber. 8643.
Water motors. Severson. 8762.
Sand moulding machines. Ph. Bonvillain & E. Ronceray, and Ronceray. 9099.
Tubular box spanners. Bedford. 9733.
Gear-cutting machines. Coventry, Smith, & Coventry, Ltd., and Anderson. 9849.
Check valves. Shaw. 9879.
Reversing-gear for steam-engines. Maxwell. 9938.
Tool for facing valve-seats. Morgan & Smith. 10336.
Apparatus for cutting and boring metals. Adams. 11322.
Process of and apparatus for treating peat. Berglund. 11971.
Motor vehicles. Hoines. 12261.
Hydraulic drilling machines. Monberg. 13011.
Reversible couplings. Stoffel & Janssen. 13528.
Aerial transitways. Collett. 13647.
Nut locks. Loutrel. 15073.
Water-turbine installations. Hallinger. 15092.
Evaporating apparatus for liquids. F. Bayer & Co. 15624.
Carburetters for internal-combustion engines. Bucherer. 15997.
Piston rings or packing for internal combustion engines. Descourtis. 16666.
Governors for variable-speed or reversible engines. Creplet. 16673.
Apparatus for washing coal and other minerals. Habets & France. 17012.
Foundry moulding machines. Bouillon. 17116.
Construction of expanding pulleys. Gray. 17147.
Valve-gear for internal-combustion engines. Evans & Wilson. 17606.
Self-starters for explosion engines. Guyot. 17989.
Machines for grinding hobs and milling cutters. Brown and Bostock. 18473.
Belt tightener. Vosburgh. 19849.
Steam super-heaters. Bruce. 20947.
Utilising the waste heat of internal-combustion engines. List. 21204.
Turbine stator blading. Bellis & Morcom, Ltd., and Jude. 21214.
Lubricators for engine cylinders. Luard. 21840.
Melt or compound for use in the hardening or tempering of steel. Brayshaw & Brayshaw. 22167.
Soldering compositions. Richardson & Richardson. 23077.
Broaching tools for cutting multiple spline grooves. Carson, and Charles Churchill & Co. 23335.

ELECTRICAL, 1912.

Electric machines. Soc. Système de Traction Auto-Régulateur. 27923.
Electric lighting system. Soc. Internationale de Lumière Froide. 28229.
Controlling electric-heating apparatus. Hulbert. 28409.
Wireless telegraph transmitters. Marconi. 28865.
Vacuum tubes for electric lighting. Skaupy. 29104.
High-tension insulators. Lodge & Lodge. 29269.
Method of diminishing the electromotive forces induced in the commutation zones of commutator machines. Heyland. 29409.
Electric motor starting and controlling apparatus. Hirst and Brook. 28634.
Machines for generating electric current for dual purposes, such as ignition and illumination. Hollister. 28748.
Electro magnets. Soc. Anon. des Etablissements L. Bleriot. 28864.
Electric circuit closing apparatus. Wade. 28977.
Regulations of the pressure of electrical generation systems employing rotary converters. Siemens Bros. Dynamo Works, Ltd., and Wilson. 29338.
Telephone systems. Automatic Telephone Manufacturing Company. 29357 and 29387.
Magneto electric machines for combined ignition and illuminating purposes. Simms. 29581

1913.

Electric measuring instruments of the mercury motor type. British Thomson-Houston Company, and Young. 1600.
Portable electric miners' lamps. Wolf. 6408.
Electric switches. Leveque-Petit. 9179.
Machines for winding or covering electric cables with tape or strip material. Fried Krupp Akt.-Ges. Grusonwerk. 9575.
Electrolytic meters. Childs and Reason Manufacturing Company. 14310.
Vacuum tubes for electric lighting. Skaupy. 14591.
Electric telegraph receiving apparatus of the selective type. Lyons. 15097.
Polyphase alternating-current synchronous motors. Crompton and Co., and Burge. 15523.
Manufacture of electric glow lamps. Wolfram Lampen Akt.-Ges. 15824.
Primary galvanic battery. Yai. 15909.
Interchangeable, alternating, and direct-current electric motor. Ashdown & Robinson. 19395.
Electric dry batteries. Rabbidge. 19783.
Railway electric signals. Evans, and J. B. Saunders & Co. 20318.
Sparking plugs. Freiberg & Petzsche. 20361.
Electric switches. Beemer. 88.
Electricity meters of the mercury motor-disc type. Lawson. 882.
Telephone exchange systems. Western Electric Company. 2509.
Electric furnaces. Wardall & Marchant. 2718.
Electric incandescent lamps. British Thomson-Houston Company. 2901.
Vapour electric devices. British Thomson-Houston Company. 5448.
Electric incandescence lamps. Zschocke. 6143.
Circuit arrangements for semi-automatic telephone systems. Siemens & Halske Akt.-Ges. 6664.
Electro-furnace. Eyermann. 9381.
Electric motors. Railing & Colf. 10535.
Regulation of electric circuits and means therefor. Siemens Bros. Dynamo Works, Ltd. 11267.
Electrically-driven automatic lathes. Kienzle. 12235.
Systems for supplying from high-pressure mains continuous-current at a lower pressure. Graham & Rickets. 15769.
Electric resonance operated apparatus. Handcock, Dykes, and Duddell. 16998.
Mercury motor electricity meters. Chamberlain & Hookham, Ltd., and Holden. 18474.
Arrangements for connecting two electrical sources in parallel. Siemens Schuckertwerke Ges. 25073.
Magneto-electric machines. Hollister. 27355.
Dynamos. Hollister. 27356.
Circuit arrangements for telephone systems. Siemens & Halske Akt. Ges. 27452.

METAL QUOTATIONS.

TUESDAY, JANUARY 6TH.

Aluminium ingot	96/- per cwt.
,, wire, according to sizes, &c. ......from	121/- ,,
,, sheets ,, ,, ... ,,	126/- ,,
Antimony	£28/-/- to £30/-/- per ton.
Brass, rolled	7½d. per lb.
,, tubes (brazed)	9¼d. ,,
,, ,, (solid drawn)	8¼d. ,,
,, ,, wire	7⅝d. ,,
Copper, Standard	£64/-/- per ton.
Iron, Cleveland	50/1½ ,,
,, Scotch	56/1½ ,,
Lead, English	£19/2/6 ,,
,, Foreign (soft)	£19/-/- ,,
Mica (in original cases), small	6d. to 3/- per lb.
,, ,, ,, medium	3/6 to 6/- ,,
,, ,, ,, large	7/6 to 11/- ,,
Quicksilver	£7/10/- per bottle.
Silver	26½d. per oz.
Spelter	£21/7/6 per ton.
Tin, block	£167/15/- ,,
Tin plates	12/9 ,,
Zinc sheets (Silesian)	£25/-/- ,,
,, (Stettin ; Vieille Montagne)	£25/2/6 ,,

The Mechanical Engineer.

AN ILLUSTRATED WEEKLY JOURNAL. Vol. 33, No. 834.

Edited by
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Telegrams: "Scientific," Manchester.
Telephone No. 6655 City.

SUBSCRIPTION RATES.

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Safety in Mining.

BLUE BOOKS as a rule are not attractive reading, but they sometimes contain valuable information, and, as the digging of it out absorbs more time than the average reader can spare, it is apt to escape the notice of many who otherwise might benefit by it. For this reason, we shall probably be rendering a service by noting some of the more salient facts and data embodied in the annual report of Mr. Redmayne, H.M. Chief Inspector of Mines, for the year 1912, just published, and especially those of engineering interest. Before touching upon them, however, we should like to point out the steady improvement in safety which has marked the accident statistics since these were first officially collected. The comparison at quinquennial periods over 60 years is very striking. Taking the last five years ending in 1912, the annual death rate from all accidents at mines and quarries, both surface and underground, was 1·81 per 1,000 persons employed, whereas in the period 1850-55 it was 4·30, or nearly two and a half times greater. The progress has continued in recent years, though naturally it is not so rapid as it was half a century ago, when big calamities were more frequent, and their causes less understood. There is still room for improvement, though the fact that no less than 589 fatalities, or 44 per cent. of the total, in the year under review arose from "falls of ground" as the result of 572 separate accidents indicates the difficulty of prevention and the extent to which workmen's carelessness contributes to them. The accident death rate from persons employed is not quite a complete measure of the dangers of mining, and it is therefore of interest to note that the diminished death rate is, roughly speaking, supported by figures based on the quantity of minerals won. The deaths per million tons of minerals raised being 4·67 for the year 1912, as against 7·48 for the year 1873.

Apart from the questions of more efficient supervision and of obedience by miners themselves to regulations designed for

their safety, on which diminution of accidents must in any case largely depend, the two outstanding causes of disaster which occupy the minds of engineers and scientists at present are the possibility of reducing the risks of explosion from coal gas and of rendering safer the use of electricity for illumination, signalling, and power purposes. To this end much progress has been made of late years through the demonstrations at Altofts Colliery of the vital part played by coal dust in initiating or propagating an explosion, and the efficacy of stone dust or other materials to prevent it, and to accurately determine which further experiments are being now conducted by a Home Office Committee at Eskmeals, in Cumberland. When these have matured, a big step will have been made in the suppression of the type of mining disaster which most strongly impresses the public, owing to the terrible fatality often involved. Other important matters concerned in this question, however, are the extent to which safety lamps and electricity may be contributory causes to disaster as the result of inefficient construction or installation. On both these points the report gives instructive information

As regards " safety " lamps, the word " safety," it is to be feared, has tended to mislead by suggesting an attribute they often did not possess and so waiving enquiry into their limitations and comparative merits. Sir Humphrey Davy's demonstrations of the difficulty of forcing a flame through a wire gauze was no doubt far-reaching as a first indication of the way in which an illuminating flame might be maintained in an explosive atmosphere, but they were far from exhausting the subject. Later enquiries have shown that to ensure real safety a number of matters have to be considered, and the report by Dr. R. V. Wheeler on the experiments that have been conducted at Eskmeals to settle some points that have for some time been doubtful. One of these is the influence of size, for obviously with a large lamp there will be a greater tendency for the flame of an explosive mixture, ignited inside it, to be forced through the gauze into the explosive atmosphere outside. With an ordinary hewer's lamp fitted with two gauzes of standard wire and mesh it is generally impossible to cause the flame of an explosion within the lamp to ignite an explosive mixture outside unless this explosive mixture is passing the lamp at a high velocity, a possible though remote contingency; but the hewer's lamp is of comparatively small size, the distance between the wick and the bottom of the gauze chimney seldom exceeding 3in., and the gauze chimney itself rarely more than 5in. in length. At pit bottoms lamps of a similar kind but larger size are used, and the question arises: At what point does the size of the ordinary gauze lamp render it dangerous? A number of experiments were made to test this point and also to decide the relative safety of lamps with single and double gauze. We cannot here go into details and must refer those specially interested to the original report, but the following general conclusions are drawn. With two gauzes, whether in close contact with the strands crossed or superposed, the flame of the most explosive mixture of methane and air (10 to 1) does not pass to the outside atmosphere when the distance between the point of ignition and the gauze is 9in. or less, but it may do so when the distance is 12in. or more, from which it would appear that the distance between the wick of the lamp and the top of the gauze chimney should not exceed 9in. With a single gauze and a similar explosive methane mixture the flame does not pass to the outside atmosphere when the distance between the point of ignition and the gauze is 2in. or less, but if the distance is 3in. or more the flame can pass through such a gauze and ignite an explosive mixture outside. In reference to the use of two gauzes, it is important to note that to ensure their efficiency they must be in close contact and that a separation of them by as much as one five-hundredth of an inch may, under certain conditions, permit the flame to pass, a fact which seems to point to the possibility of obtaining the safety of the double gauze by the use of single gauze made from wire double the " width," or from perforated sheets of double the thickness. Tests with the most explosive mixture of coal gas and air (7 to 1) showed that the flame can pass through two gauzes and ignite explosive mixture outside when the distance between the point of ignition is only 8in., and even 5in. is sufficient if the gauzes are not in close contact. These results are different from those obtained with methane, and, the report points out, shows the fallacy of basing conclusions respecting the behaviour of safety lamps in mine atmospheres solely on experiments with mixtures of coal gas and air.

Although electricity continues to make steady progress in its application to mining, there is no denying the existence of a good deal of mistrust amongst men as to its potentialities for mischief and considerable justification unless precautions are taken. These are not difficult to secure, but it is essential that electrical installations should be supervised by competent men. The great majority of electrical " accidents " that have occurred have arisen from conditions which should have been avoided, and, as preventable occurrences therefore, do not strictly speaking deserve this designation. In the course of eight years, from 1905-12, there were 71 deaths recorded from electrical shock below ground as a result of 69 recorded accidents, and out of this number no less than 34 deaths from 32 accidents arose from the simple absence of, or inefficient, earth connection. To those who have not given attention to the matter, this may seem somewhat extraordinary inasmuch as the making of an " earth " where mining machinery is concerned seems such a simple matter. This, however, is not always the case, and we have more than once touched on it in these columns.* In damp pits there is no difficulty, but in dry ones nothing short of direct cable connection to a wet sump can be regarded as effective.

The risk of ignition of firedamp by electricity has often been discussed, and, while there is no question that the ordinary voltages used for power are easily capable of causing dangerous sparks, and hence necessitate careful protection of electrical machinery, doubts have been expressed as to the possibility of ordinary signalling bell wires creating sparks sufficiently powerful to ignite gas. In view, however, of the circumstances attending a fatal explosion which occurred at Bedwas Colliery, South Wales, there seems no longer room for doubt. The bell was an ordinary one worked by a battery of eight Leclanche cells, which, tested after the accident, gave 11½ volts, and it was proved experimentally that not only were sparks from this battery capable of igniting an explosive mixture of coal gas and air, but that such a mixture could be fired by sparks produced by rubbing a file across two wires connected to a pair of cells giving only 4 volts pressure. This, it would appear, is the first recorded case of a firedamp explosion caused by sparks from an electric bell, and, in view of the low voltage necessary, not only deserves noting, but, we think most people will agree, justifies the Home Office regulation that requires all cables, signalling wires, and signalling instruments to be protected so that there is no risk of open sparking.

* See issue March 14th, 1913, page 274, Vol. XXXI.

Bradford Boiler Explosion.—The formal investigation ordered by the Board of Trade to be held in connection with the boiler explosion at the Valley Dye Works, Bradford, is fixed for hearing in the Town Hall, Bradford, Yorkshire, on Wednesday, the 21st inst., at 11 a.m.

SUPERHEATING STEAM IN LOCOMOTIVES.

At a meeting of the Institution of Civil Engineers held on the 13th inst., a paper on "Superheating Steam in Locomotives" was read by Mr. Henry Fowler, A.M.Inst.C.E. The utilisation of steam superheated, or of a higher temperature than saturated, had, he remarked, engaged the attention of engineers since the inception of the use of the expansive power of steam, *i.e.*, since the middle of the eighteenth century. Its application in locomotives was suggested over 85 years ago, and for half a century many attempts were made to employ it in this class of engine. Owing to trouble arising from the packing and the lubrication, these were not successful, and the prominent position it occupied at the present day was very largely due to the investigations of Dr. Wilhelm Schmidt, of Cassel, and to the practical trials of his apparatus made by Mr. R. Garbe, of the Prussian State Railways. Various types of superheaters were tried, but the one now in most general use was that in which the steam received its superheat when passing through small tubes placed in large smoke tubes through which the heated gases travelled on their way from the firebox to the chimney. This type was general in this country, where, in addition to the Schmidt system, the Swindon and Robinson systems, which differed from the Schmidt in detail only, were also employed. The utilisation of the heat in smokebox gases had been tried repeatedly, but without much practical success.

Under ordinary conditions, when an engine was running, the steam passing through the superheating elements carried away with it sufficient heat to keep the metal of the elements comparatively cool. When, however, a locomotive was running down an incline without steam, this did not occur, and it was necessary to prevent the gases from passing through the fire tubes, which was effected by a damper or some other type of retarder. Arrangements were generally made for working the dampers or retarders automatically. The connection between the superheater elements and the header from which steam was distributed was a matter of importance, and the methods by which this was done constituted one of the chief differences between the various fire-tube superheaters. Essentially, however, they comprised those in which a joint was made between the pipe and the collector and those in which the former was expanded into the latter.

Piston valves were used almost exclusively in locomotives using superheated steam. These had to be of special design, owing to the greater fluidity of superheated steam and to the difficulty of efficiently lubricating any surface to which highly superheated steam had access and which had a heavily loaded machine part passing over it. For the same reasons special attention had to be paid to the design of the piston head. The high temperature of the steam necessitated glands of special design wherever they were required, as well as arrangements for cooling the glands by allowing access of air where possible. The packing used required to be of special high-melting composition, and here, as elsewhere, it was necessary to design the parts so that as little pressure as possible existed between two surfaces which were exposed to the temperature of the highly-superheated steam. The oil used for lubrication was generally a mineral oil which had a high flash-point, and which was fed into the various parts by a mechanical lubricator which would ensure a definite predetermined amount of the lubricant being delivered regularly at the necessary points. The provision of a pyrometer which allowed the engine driver to know at what degree of superheat he was working was advisable.

Owing to the use of piston valves which did not permit the relief of compression or suction in the cylinders when running with the regulator shut, it was, he observed, necessary to provide by-pass and vacuum relief valves. Some of these valves were also suitable for dealing with any water which might be carried over into the cylinders, whilst in other cases special relief valves were fitted. The large tubes in which the superheater elements were placed gave little trouble in this country.

The greater volume of superheated steam, when compared with saturated, had in many cases led to the adoption of larger cylinders and lower boiler pressure. This, he said, led to economy in boiler repairs, which should counterbalance the increase of maintenance necessary for the extra apparatus required when superheated steam was used. The degree of superheat usually employed was 230° to 260° Fah. No figures at present seemed to be available for the variation in the economy with varying degrees of superheat.

The chief advantage claimed for the use of superheated steam in locomotives was the economy in coal consumption, and on the Midland Railway a number of trials had been made to ascertain what this was with the various types of engines, the comparison being made on the consumption per ton mile under circumstances as nearly comparable as possible. These trials showed that a saving of 23 per cent. in the coal consumption and of 22 per cent. in the quantity of water used was obtained in one case, whilst in another, where the difference between the locomotives was solely in the superheater, the saving of coal was as high as 30 per cent. This high figure was probably due to the engine which used superheated steam having more reserve of power than the one employing saturated steam. From diagrams of these two engines it could be shown very clearly how much more fluid superheated steam was than saturated. Experiments had been carried out to ascertain the effect of superheating the steam supplied to the high-pressure cylinder of a 3-cylinder compound locomotive, and it had been found that a saving of coal of 25·9 per cent. and of water of 22·3 per cent. had resulted when comparison was made with a similar engine using saturated steam. In tests carried out with goods engines, the coal saving had been from 14·3 per cent. to 18 per cent.

TRANSMISSION OF POWER BY CHAINS.

In a paper on this subject read before the Manchester Association of Engineers, on Saturday last, Mr. H. T. Hildage, M.Inst.C.E., said that during recent years great progress had been made in the development and improvement of prime movers for the generation of power, and in some cases also in the improvement of the machines that used the power. But comparatively little attention had been paid, as far as factories and workshops were concerned, to the study of the transmission of power by mechanical means, and in consequence this had become the weakest part of many of our manufacturing organisations. So much was this the case that the remodelling, improving or tuning up of the distribution and transmission of power, was one of the most fruitful fields that could be exploited by reformers who were seeking either to lower production costs, or to improve the quality of the product. The drives in most common use were rope and belt drives. Both these methods of transmission were subject to losses from three causes: (1) The friction in the bearings of the shafts due to the initial tension in the rope or belt. (2) The stiffness of the rope or belt. (3) The creep of the rope or belt on the pulley, caused by the fact that the band itself did not leave and enter the wheel under the same tension, and consequently changed its length, being elastic. Assuming that the drives were properly designed and worked under favourable conditions, the sum of these losses might be from 7 per cent. to 15 per cent.

Turning to the positive or rigid means of transmission, such as spur wheels, helical gearing and bevel wheels, they were, he remarked, generally used when the distance between the shafts, whilst being on the whole rather short, could be fixed more or less to suit the requirements of the transmission. The calculated efficiency of these methods of transmitting power was very high. Spur gearing was not generally applicable to the driving of machines from line or counter shafts, the distances between the shafts to be connected were not suitable, and if they could be arranged so that they were suitable there would be too much possibility of variation for efficient working. In those ordinary workshop transmissions for which tooth gearing of this character was available, the principal difficulty was in the high degree of accuracy that was necessary, not only in the forming of the tooth surfaces, but also in their location, and the great effect in reducing efficiency and increasing noise and vibration that resulted from any departure from this accuracy.

The ideal transmission should have the following characteristics: (1) Positiveness. (2) High efficiency. (3) Flexibility

(4) Absence of narrow or rigid limitations as regards distance between shafts. (5) Durability. (6) Quietness of running, and freedom from vibration. (7) Low cost, both for installation or maintenance. (8) Elasticity of speed ratio.

The author then proceeded to consider chain gearing as a possible solution of the problem. Chain gearing was, he observed, a positive transmission. Experiments made for the purpose of measuring the efficiency of chain drives had shown it to be between 96 and 98½ per cent., and in these cases the losses included not only those due to the chain itself, but also those due to such part of the resistance in the ball bearings of the motor and generator as were induced by the driving pull on the chain. Chains were quite as flexible as belts or ropes, and their flexibility did not depend upon any bending of material. There were limitations of the distance between the centres of shafts to be connected, but they could not be said to be either narrow or rigid. The minimum centre distance for a chain drive was the sum of the radii of the smallest wheels that could be put on the shafts to give the required ratio of reduction, and this in general did not exceed the centre distance for a corresponding spur wheel drive. The maximum centre distance, which to some extent depended upon the inclination or "lie" of the drive, was about 20ft. Chain drives were usually quiet, free from vibration, and sufficiently durable to be reliable and economical. In first cost, the mere substitution of a chain for a belt or rope, without any other change in the conditions, would not, as a rule, be economical. In all probability a chain drive would often cost more than a spur wheel drive for which it was substituted. But if it were possible to remodel the conditions of a rope or belt drive, so as to make them suitable for chain gearing, the total cost of the installation would usually be less with chain gearing than with belts or ropes, because shorter centre distances would be used, larger ratios were possible, and other modifications and economies in design and arrangement would be made. Again, if cost be defined as the total cost, including first cost, maintenance, depreciation, interest, and power absorbed in transmission, it was comparatively easy to demonstrate that chain gearing was much cheaper, where it was applicable, than non positive drives. As regards elasticity of speed ratio, in the present state of its development chain gearing would not readily fulfil this requirement.

A satisfactory chain should fulfil the following requirements. (1) It must be so formed as to be capable of gearing with suitable wheel teeth, in such a way that it would enter and leave the wheel without great loss of power, and without noise. (2) The joints must be so designed and made as to be capable of resisting wear for a long period of time. The requirements of satisfactory wheels were (1) That the tooth form should be such that a suitable form of chain link would come into gear with it, with as little impact as possible and without friction, would remain in gear with it, and would leave it freely and without friction. (2) Small increases in pitch of the chain due to inevitable wear, must not detract from the satisfactory fulfilment of the first condition.

There were two principal solutions of these requirements, one of which was considerably nearer perfection than the other, the other, however, had certain advantages that justifies its adoption in many cases. These two solutions were the so-called silent and bush roller chains, which were described in detail. A description of these chains was given by the author in a paper read before the Rugby Engineering Society, on November 19th, 1912, and reproduced in our issue of November 29th, 1912 (see page 688, Vol. XXX.). The paper concluded with a description of chain driving as applied to various machine tools, &c.

Formulas for Flux and for Solder.—The following fluxes for soldering and welding various metals are given by W. E. Rhodes in the "Electrical Review and Western Electrician." For steel and iron use sal ammoniac or borax; for zinc use chloride of zinc; for lead use tallow or rosin; for brass use sal ammoniac or sulphuric acid. The best solders for different metals are as follows. For lead use two parts tin and three parts lead; for tin use one part tin and two parts lead; for aluminium-bronze use four parts copper, four parts zinc, and three parts borax; for aluminium-brass use 70 parts copper, 30 parts zinc, and five parts aluminium; for bronzing use half copper and half zinc.

THE USE OF OIL FUEL IN MARINE BOILERS.*

BY JAMES S. GANDER.

I PROPOSE to confine my paper to the practical details of installation and maintenance dealing with several methods of burning oil fuel in marine boilers. At the present date there are many systems in vogue, but in the merchant service we may divide these various methods under three headings: (1) Steam with oil. (2) The direct-pressure system. (3) The compressed-air system. The steam with oil appears to have been the earliest successful method, although at the same date, in 1865, a very serviceable burner of the hot-air blast type was introduced into this country. The direct-pressure burner was patented at a much later date.

In order that this paper may be of some practical value to those who have not yet acquired what we might call oil fuel experience, I shall commence at the first cycle of operations—bunkering—and endeavour to explain as we proceed, the various important details and the precautions that must be observed in order to burn oil fuel successfully with any system. It will be seen later that it is of vital importance to have clean bunker spaces. The fuel bunkers of a vessel which has been undergoing repairs should be thoroughly cleaned out, and then examined by a responsible engineer before any fuel is taken aboard. It is a common practice to clean these spaces with sawdust and bagging, and workmen are apt to leave these materials in the bunkers, especially in the double bottoms. Should this item be neglected we may reasonably expect to throw heavier work on the filters, and consequently on the staff. Once these fuel spaces are cleaned in an efficient manner they may be expected to remain so as the installations supplying the fuel take every care to extract any impurities, and further, a filter box of a coarse mesh can be fitted in the filling line. Even with fuel containing impurities a system can be efficiently worked by attention to the filters, but the little labour involved in the cleaning of the tanks is one which is well repaid.

The operation of bunkering is a very simple matter, and rapidity of loading depending on the size of pipe through which the bunkers are received. The quantity can be accurately ascertained in a few minutes by measurement with a tape line. Usually, drawings are provided giving the bunker capacities per foot depth; in any case it is an easy matter to graduate a tank by running up 10 tons at a time by arrangement with the installation supplying the fuel, and taking note of the ullages in each instance. Measurements taken in this manner are often found more reliable than builders' figures. After loading, the water finding test may be applied to the first tank loaded, and if any water be present, a few inches or so from the bottom, the tank should be pumped into a settling tank where the water may be readily separated by means of the heating coils, and drawn off.

The Steam with Oil System. Fig. 1 shows the fuel burning arrangements of the S.S. "Murex." This vessel has been fitted for many years with the steam with oil system, with Wallsend burners. A gravitation tank is fitted at the port and starboard side in the 'tween deck, fitted with steaming coils for the separation of water, and with drains for running the same. The exhaust from the steam coils can be carried to the waste water tank or to an observation tank. The filling lines to these tanks are so arranged that they may be filled at the same time as the bunkers, and it is a good practice to run a few tons first into these tanks and thus catch and dispose of any water which may have been present in the ship or the shore pipeline. In Eastern climates it is not necessary to use the steam coils, as the temperature of the bunker deck is sufficient to assist in the separation of water from oil. At a temperature of about 100° Fah. the water mechanically separates by reason of its gravity. If a more complete separation is desired it is necessary to heat the mixture to about 140° Fah.

Before lighting up fires any water in these gravitation tanks must be run off. This is easily done in the aforementioned manner. If the vessel be in a port where it is not advisable to drain overboard, the water may be run into the oil bilges which are quite distinct from the ordinary engine-room and stokehold bilges. A special connection is fitted to the fuel pumps for draining these occasionally. The gravita-

* Paper read before the Institute of Marine Engineers, December 15th, 1913.

tion tanks in the illustration have a capacity of 12 tons each. One of the two fuel pumps in the stokehold delivers the fuel to these tanks from any of the bunker spaces or double bottoms—usually the after cofferdam is used for greater convenience in measuring daily consumption. A suction is fitted to each wing of the cofferdam, which is divided by a longitudinal bulkhead. One is a high and the other a low suction. The high suction, about 4ft. from the bottom of the tank, is used at sea so that no impurities can be drawn into the fuel system. The low suction is used for draining water or for emptying the tank.

These tanks run for 12 hours each before changing over. The operation of changing over should have no effect on the fires. The incoming tank must be opened up before closing down the outgoing one. Sometimes a little smoke appears at the funnel caused by the difference in the head of oil of the two tanks. This may be anticipated by easing the oil valves

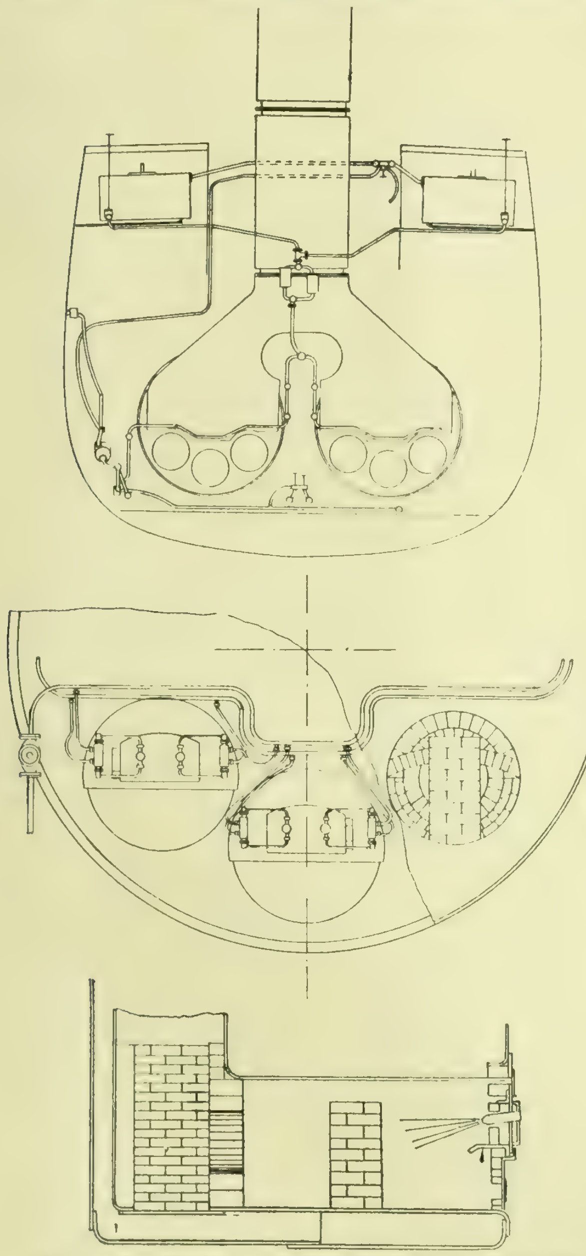


FIG. 1. ARRANGEMENT OF OIL-FUEL SYSTEM ON S.S. "MUREX."

in a little before changing over. It is the duty of each engineer, before going on watch, to take soundings of the gravitation tanks and enter the figures in the scrap log so that the consumption may be gauged. The oil flows by gravitation, hence the name, and passes through filters or strainers on its passage to the burners. The filters are in couple for cleaning purposes, and under ordinary circumstances will not need changing more than two or three times a week. In heavy weather they will need cleaning more often, as the rolling of the vessel tends to stir up any impurities which may be present in the oil.

After passing through the filters and then through the small intermediate oil valve attached to the burner brackets, the oil reaches the burners. A burner in section is shown in Fig. 2. This burner is of the ordinary type, generally known as the Wallsend type, and is the same as the Rusden & Eeles burner. If required, it forms a very efficient burner for the compressed-air system, in which case the air should be heated before reaching the burner by carrying the supply pipe through the smokeboxes, much in the same manner as in a forced-draught system. In docks, where a steam supply is not available for lighting up, in the event of all ship's fires being out of action, steam may be easily raised by cold compressed air until a pressure of about 20lbs. is attained, when the air supply may be shut off and the steam for atomising drawn from the boiler. The steam supply enters at the top of the burner and the oil at the bottom. The section clearly shows the steam jacket which is formed around the oil. The steam, after passing round the jacket chamber, enters the hollow spindle through small holes, and its emission from the burner is controlled by an interior spindle. We have thus two separate spindles—one controlling the steam and the other the oil supply. Further adjustments may be arranged by the steam and oil valves on the side brackets.

Situated as they are in an average temperature of 100° Fah. (in Eastern climates) the gravitation tanks need no additional heat from the steam coils, and the oil is further heated a few degrees by contact with the pipes on its passage to the burners. In temperate and cold climates it is advantageous to use the steam heating coils and raise the oil to about 90° Fah. With the steam with oil system the temperature of the incoming oil is not so important a matter as with the direct-pressure system, for the appearance of the flame indicates correct combustion or otherwise, and any deficiency in the heating of the oil from the gravitation tanks may be remedied by a slight adjustment of the steam supply to the burners where the steam jacket gives to the oil the required additional heat.

At the burners the oil is heated by the steam jacketing and shoots into the furnace in a spray of conical shape accompanied by the steam, which atomises or partly splits the oil into its constituent elements. Should the washer separating the steam and oil supplies inside the burner leak, it will be noticed that incandescent sparks of carbon issue from the burner. This has been caused in the first place by the man in charge altering the steam supply to overcome supposed defective heating, with the result that too great a supply of steam coming into direct contact with the oil inside the burner atomises the same too completely, and separates the gases almost entirely from the carbon contained in the oil. These washers last six months or more, and no trouble need be apprehended from this source.

Before lighting fires, after they have been out of use for a considerable time, it may be necessary to heat the oil in the gravitation tanks, and to circulate through the supply pipes to obtain a uniform temperature of about 90 to 100 Fah. The steam pipes should be well blown through to clear water and heat up the burners, and then the steam valve opened very slightly. With a lighted torch held a few inches in front of the burner inside the furnace, and the oil valve opened very slightly, immediate combustion takes place. For a few minutes the combustion is not perfect till the brickwork gets heated, but in a very short time the fires should be burning without smoke. It is advisable to light all fires together and not to raise steam with only one burner in each furnace, as the heating effect in the first instance is much greater with oil than with coal; also to set the burners away very easily, otherwise we may generate steam much too quickly for good boiler practice. For the first few minutes the fires should be set away fairly full in order to heat up the brickwork and then eased down to a minimum.

Efficient circulation should be maintained up to about 30lbs. pressure, as with coal burning. In boilers fitted with hydrokineters steam can be safely raised more rapidly if these be opened some time before lighting up say two hours. With respect to the use of hydrokineters it should be remembered that if these be opened too far, excessive vibration of the boiler is caused, and any deposit at the bottom of the shell is likely to be shaken up and deposited on heating surfaces. Should the fires have been set away too rapidly the best practice is to shut down altogether when steam begins to show. So efficient is oil fuel as an agent for raising steam that one has to guard against the too rapid generation by

inexperienced firemen—on the other hand, by observing the known conditions, no other method of firing is so easy of adjustment, both for raising steam and for manœuvring with engines in and out of port. So effectively can the adjustment of the valves be arranged that a vessel can go from full speed to slow without previous notice, and not lose steam through the safety valves. With coal we should have to partly draw fires, with a loss of fuel, to the detriment of the backends, and then not succeed in preventing the boilers from blowing off.

An important item in the combustion of oil fuel with this system is the regulation of the pressure of steam supply to the burners. I find from practical experience that the most economical pressure ranges from 25lbs. to 35lbs. per square inch. This, of course, is arranged in the reducing valve. Strange to say, the consumption of water for burner steam is not greater, and in my opinion less, than the consumption when running the steam supply at 60lbs. This is accounted for by the fact that steam at 30lbs. from the same reducing valve and main boiler supply will be drier than reduced steam at 60lbs. under the same conditions. This is an important feature in the proper pulverisation of the fuel. I prefer the lower pressure for the following reasons: (*a*) The burner flame can be adjusted through a greater range. With too high a steam pressure and when running burners at a minimum there is a slight possibility of the flame blowing out. (*b*) Better combustion of the fuel, as evidenced by the reduced consumption and reduced funnel temperatures. (*c*) With the low pressure there is no danger to backends should the striking pillar get knocked down without being observed by the engineer on watch. (*d*) Decreased consumption of water.

The burner steam should be connected with the auxiliary steam line and should have a separate connection from the donkey boiler. The proper adjustment of the steam and oil valves is a matter which needs very little practice to obtain the best results. The flame jet from the burner should form at a distance of 2in. or 3in. from the nozzle, and not start directly from the burner, as this tends to deposit carbon on the end. The burner should be set in a central position with regard to the striking pillar, and pointing downwards at an angle so that both the vertical and horizontal centres are struck. To facilitate the manipulation of the flame jet the burner is mounted on trunnion joints at the bracket end of the supply pipes. Burner spindles should be set correctly at the commencement of a voyage, and any regulation of supply arranged from the side valves. By this means we insure that the flame always strikes the pillar at the correct position for economy. When this is the case the incoming air supply mixes equally with the primary products of combustion, and the deposit of carbon is prevented. With clean burners and filters at the commencement of a voyage, proper attention to filtration and the setting of the burners in the first instance, the latter will not require cleaning for several months. The burners are detached in a few seconds and usually a spare burner is fitted on trunnions ready to be swung into position should the other on the furnace need overhauling. One burner in each furnace is sufficient for all ordinary purposes.

The brickwork of the boilers should be well laid, that it may stand heavy weather. The position of the striking pillar and the area of opening at the neck of the furnace are important factors: without a well-arranged brickwork it is impossible, however well other parts of this particular system may be designed, to obtain the best results. The striking pillar acts as a retarder to the otherwise too rapid passage of the flame, assists the furnace to perform the duty of a heating surface, and, being heated almost to a white heat, helps that particular stage of combustion which takes place in its vicinity. Without a striking block we might be using the combustion chamber as a furnace and the uptake as a combustion chamber.

The sides of the pillar are strengthened in a simple manner against heavy rolling by the addition of side arches. The area of opening at the end of the furnace should be such that an average man can enter without having to pull down brickwork. A circle of 18in. diam. is sufficient. It will be seen from the drawings here shown that the back brick rings enter the combustion chamber for half their length to give support to the brickwork round the saddle plate. The bricks in the combustion chamber are carried to an all-round height of 3in. below the bottom row of tubes. The masonry should last from one docking to another, with the exception of the striking block, where it is necessary to remove the top two rows for access to the backends. Sometimes a brick is loosened by a careless fireman removing the carbon product of incorrect combustion. This may be anticipated by supplying the firemen with light steel-tipped slices of ⅞in. diam., which will remove carbon without damaging brickwork. All studs and nuts for coal burning gear support are fireclayed over.

The incorrect adjustment of the steam and oil valves may cause a heavy smoke at the funnel and a carbon deposit on the striking pillar. It is generally possible on most vessels to obtain a view of the funnel from below, and smoke can be entirely prevented by examining the appearance of the flames in the various furnaces and regulating those at fault. A thin smoke is rather desirable, as it is an indication that steam is not being wasted up the funnel. Smoke can be immediately stopped by giving additional steam to the burner or decreasing its oil supply by means of the bracket valves.

The appearance of the flame in the furnaces, in colour and in form, gives indications of economical combustion or otherwise, and very little experience is necessary to appreciate the differences. With perfect combustion the flame stream commences 2in. or 3in. from the nozzle, the intermediate space being filled by a greyish vapour, and wraps symmetrically around the striking pillar in a blaze of brilliant white slightly tinged with yellow. Too brilliant and too white a flame means that too much steam is being used. Excess of steam

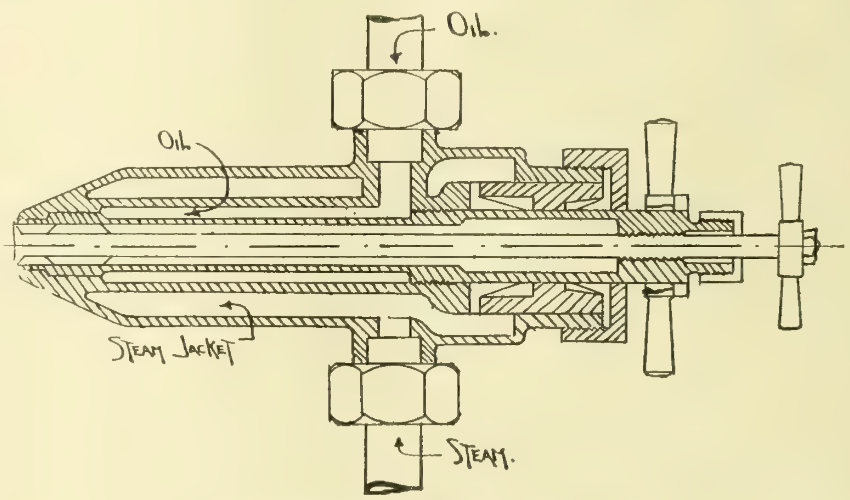


FIG. 2. RUSDEN & EELES TYPE OF OIL BURNER.

gives a bluish transparency at the point of contact. With too much oil the flame assumes a deeper yellow tinge and streaks of dark will be observed in the stream from the nozzle. An excess of oil will cause smoke in the furnace and a yellowish-red colour to the flame. Still more oil being supplied to the burner, the mixture does not atomise and is deposited in a liquid state on the striking block.

The presence of water in the fuel has a retarding effect on the decomposition by robbing the gases of the heat necessary for pulverisation. A slight percentage will have a cooling effect on the striking block and larger quantities will cause portions of the oil to be deposited on the striking block in the form of carbon. It is a difficult point to say exactly what percentage of water may be present in the oil without having a serious effect upon the fires, as the water separates mechanically on its passage to the fires and in the gravitation tanks. In an experiment made with special apparatus the actual energy lost by the presence of water in the fuel was found to be 13·14 B.T.U. per 1 per cent. water in addition to that lost by the absence of the quantity of oil which it replaces. In a ship burning 20 tons fuel per day with a 1 per cent. mixture of water and assuming the value of the fuel at 18,000 B.T.U., the evaporative power of the boilers at the given consumption is decreased by more than 1 per cent. It is therefore an important matter to separate the water, if any be present. This is easily done in the gravitation tanks, and proper attention should be given by examining the drain cock on the tank before changing over.

The point has frequently been raised as to whether steam used for pulverisation is actually burned itself along with the other products of the primary combustion consequent on the formation of hydrogen and carbon monoxide. If this were true the energy generated by the combustion of this steam should to some extent balance the steam supplied from the boiler for his purpose, which may range between 5 and 10 per cent. of the total evaporation. In practice this is found to be a fallacy, and we may safely assume that any heat so generated only balances that given out by the burning gases to decompose the steam.

The air supply to the bottom of the furnace should be regulated by movable dampers, the quantity of air to be supplied depending naturally on the rate of combustion. The full opening of the dampers of an ordinary marine boiler under running conditions should be about 30 sq. in. per ton fuel consumed. This gives for an ordinary boiler an opening of about 9in. by 6in., and this may be reduced if possible, as too great an air supply tends to delay combustion. When running at reduced speed the dampers ought to be closed in as far as possible without forming smoke. On no account should the damper be full open when running easy, as a current of cool air is set up which may have a bad effect on tubes, exactly as with coal burning.

On finishing with boilers all ashpit and main dampers must be shut down, and it is an advantage to turn ventilators of the stokehold back to wind and close storm plates. Just as the initial heating effect of oil is greater than that of coal, so also is the cooling effect when fires are shut off, as we have no fires to burn down, with a waste of fuel, as in the case of coal burning.

So far as marine boilers are concerned the principal, and we might say the only, drawback to the steam system is the water consumption. Authorities differ widely as to the percentage of steam generated in the boilers for burner use compared with the total evaporation. The lowest figures available are those of the United States Liquid Fuel Board, at a trial of a Hayes steam burner. The percentage obtained in this case was $4\frac{1}{2}$ per cent. of the entire evaporation. We must, however, remember that, in the words of the report "This boiler was piped to furnish steam for the steam burners, and has no other pipe leading from it." To compete with such a result on a sea-going vessel we require an impossible evaporator with an efficiency of 100 per cent. and no blowdown or condensing losses.

In the case of the s.s. "Murex," whose fuel-burning arrangement is shown on Fig. 1, the consumption of water for all purposes, so far as engines and boilers are concerned, amounts to 10 tons per day. Allowing for engine and auxiliary losses $2\frac{1}{2}$ tons, we are consuming $7\frac{1}{2}$ tons per day for burner steam. Assuming an average evaporation of $14\frac{1}{2}$lbs. of water per pound of fuel, and a consumption in main boilers of 17 tons fuel per day, the percentage works out at three. In actual practice, when making up the feed from an evaporator, the condensing and blowdown losses considered with the efficiency of the evaporator raise the ratio to 5 per cent. In other words, on a consumption of 17 tons per day $\cdot 85$ tons fuel is used in making up burner steam supply.

The steam with oil system has the merit of absolute simplicity, and where a cheap supply of fresh water is available such as in river boats, and for shore installations will probably hold its own for some time yet on account of the cheapness of first cost. For ocean-going steamers the direct-pressure system is found to be far more economical, the additional first cost being repaid in a few months by the 5 to 8 per cent. saving of fuel which may be expected.

(To be continued.)

Lubricating Rails on Sharp Curves. On railway tracks where the curves are excessive it is usual to lubricate the rails in order to ease friction due to the normal revolution of the wheels being either forced or retarded on the outer and inner rails respectively, owing to the disparity in their length. This is generally done by hand, but on the Liverpool overhead line, and others, an automatic arrangement invented by Mr. E. S. Neachell, of that line, has been adopted. This labour-saving device consists of a grease box by the side of the line, with a deflection bar attached to the rail. Every wheel that passes over the bar depresses the latter, which actuates a ratchet and pawl, whereby a spurt of grease is placed on the side of every wheel, before it reaches the curve.

MÜLLER'S STEAM-CONDENSING PLANT.

THE accompanying illustrations show an arrangement of steam condensing plant, the invention of Mr. Paul H. Müller, 11, Heinrichstrasse, Hanover, Germany, wherein the cooling water supplied to the condenser and the water for operating an air ejector of the water-jet type for drawing off the air and other non-condensable gases from the vacuum space of the condenser are supplied by means of the same circulating pump. Fig. 1 represents a side elevation of the plant, and Fig. 2 is a vertical longitudinal section of the primary air-separating tank. A represents a circulating pump which is connected by means of the main supply or suction pipe B with a river or pond C. The circulating pump A lifts the cooling water and forces it under pressure through a pipe D provided with a valve W, to the cooling space of a surface condenser E. The exhaust steam from the steam engine is delivered to the vacuum space of the condenser and the water of condensation is drawn off through a pipe V at the lower part of the same. The water used for cooling in the surface condenser is conducted through a delivery pipe F to an elevated tank G. A branch pipe H of the pipe D is bent in downward direction and provided with an air ejector J and a water-delivery pipe K below the same, this air ejector being operated by a portion of the water supplied by the pump A. The air ejector J is connected by an air suction pipe O with the vacuum space of the surface condenser. The velocity of the water is converted into pressure and the mixture of air and water is delivered by the pipe K into an air-separating

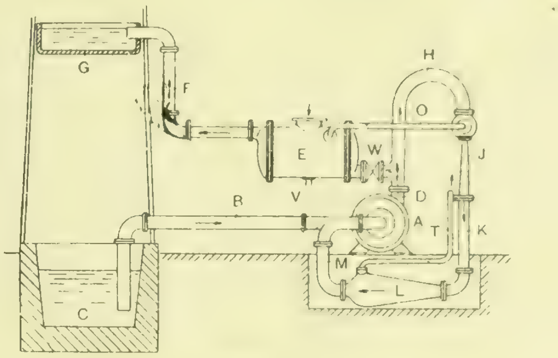


FIG. 1.

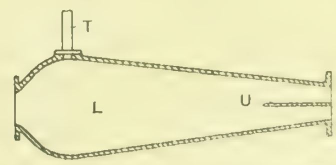


FIG. 2. MÜLLER'S STEAM CONDENSING PLANT.

tank L, which, as shown in Fig. 2, is formed with a conical enlargement. Owing to this conical enlargement of the tank the velocity of the water entering the latter is considerably diminished. The out-going end of the tank L is diminished in size or contracted so as to permit the even flowing off of the water through the pipe M into the main supply or suction pipe B of the circulating pump A. For preventing the turning of the water in the tank on the longitudinal axis of the same there is arranged in the inlet end of the tank in the longitudinal centre plane of the same a short partition wall U. The water gradually assumes a reduced speed in its horizontal passage through the tank, so that the air carried along by the water is separated from the latter and collects at the upper widest portion of the tank, where it is conducted into the atmosphere by an air outlet pipe T, which is made of sufficient height so as to retain the water therein at any variation of pressure in the tank L that might occur during working. The de-aerated water is now conducted through the return pipe M back into the suction pipe of the pump, where it is mixed with the colder water drawn up by the pump. The separation of the air from the water is an important feature, as the air is thereby prevented from passing with the water into the pump and impairing the proper working of the same. The pressure with which the air ejector is worked is determined by the height of the tank G and the resistance of the condenser.

SIZE OF VESSELS AND DEPTH OF HARBOURS.

THE effect on the world's harbours of the present deepening of the Suez Canal and the capacity of the Panama Canal is discussed by Lord Pirrie in a memorandum which he has submitted to the Dominions Royal Commission. He states that these canals, by providing for the passage of larger vessels than those at present engaged on the routes involved, will encourage shipowners to build vessels up to the maximum dimensions which they will pass, and so increase the demand on the part of shipping for an increased available depth in the principal harbours of the world. There is no doubt that the minimum working depth now desirable for a first-class harbour is at least 40ft., and in view of the time which it takes to get harbour authorities in motion, and to obtain results from them, Lord Pirrie thinks the minimum depth which harbour engineers, or any report on harbour facilities, should now recommend is at least 45ft. Lord Pirrie states that his firm has recently built by far the largest vessel yet put into the Australian trade, and, provided Australian harbour facilities permitted, he would not be justified in setting any limits for vessels in such a trade.

Sir John Harvard Biles, discussing the economic size and speed of steam vessels, states that, if unrestrained draught be attainable, a fleet of a few large steamers is more economical for cargo-carrying than a fleet of a large number of small steamers. The tendency to increase the size of ships is indicated by the fact that in 1913-14 there were 29 ships between 15,000 and 20,000 tons, as against 17 in 1912-13, while the total number over 10,000 tons was 206 in 1913-14, against 177 in the previous year. As far as the distant dominions are concerned there would appear to be little advantage gained by any practicable deepening of the Suez Canal. The rate at which the canal has been deepened would, if continuously applied, take many years to reach 40ft., and even then there would be no appreciable gain in using the canal for the far-off dominions. As far as India and China are concerned, there would still be an advantage, on account of distances saved. It may be that the increased draught available in the Panama Canal will make it possible to run more economic steamers of greater length to China, in spite of the greater distance. He states it is not unreasonable to predict that within 20 or 30 years a depth of harbour of 60ft. could be profitably employed.

Sparks in Mines: Low-voltage Tests. In the course of the evidence tendered at the inquest on the victims of the Senghenydd Colliery, Mr. C. P. Sparks, M.Inst.E.E., of the firm of Messrs. Sparks & Sons, Moorgate Court, London, said that he inspected the electrical signalling apparatus at Senghenydd in company with Mr. Nelson, the Electrical Inspector of Mines. Starting with the general statement that making and breaking contacts caused slight sparking, he said he conducted experiments most favourable for ignition. On January 1st there was a series of tests as to whether there could be ignition. An explosive mixture was obtained, and inside a chamber 18in. deep a bell was hung. The mixture of gas and firedamp air was passed through the chamber. The maximum conditions were observed. Many hundreds of signals were given, but it was found impossible to fire the mixture. To increase the intensity of the test the cover was removed from the bell. Although a spark was given off it was not of sufficient intensity to ignite the mixture. They began with 9 volts and went up to 13½ without result. They then put 50 per cent. more on to the current and 50 per cent. on to the pressure, and yet the gas could not be fired. Town gas and air did fire. They further experimented up to a 10 per cent. mixture with 18 volts, but nothing happened. The witness produced a sample bell and an actual bell used in the signalling system at Senghenydd. His conclusion was that no ignition took place, and he based this view upon the internal condition of the bell at engine-room No. 2 and the bell at the drum engine-house. The working pressure and the current in this system were insufficient to fire the mixture.

WATER SOFTENING AND PURIFICATION.*

BY H. J. DE Q. LENFESTEY, F.C.S.

(Concluded from page 25.)

HAVING recounted the various impurities found in waters used in boiler feed and other purposes, I shall now proceed to investigate the various means by which these objectionable impurities may be removed. As previously stated, the carbonates of lime and magnesia are held in solution by means of loosely combined carbonic acid. In order to remove these compounds, therefore, it is only necessary to provide some means by which this loosely combined carbonic acid may be severed from its connection with the neutral carbonates. This can be done mechanically by means of heat. On boiling water the carbonic acid is driven off and the carbonates of lime and magnesia are precipitated. This, however, is a very expensive process, unless a large quantity of exhaust steam is available, and then means must be provided for removing the oil which is conveyed to the water from the exhaust steam. Boiling, however, is not sufficient in the case of bi-carbonate of magnesia, for this compound is soluble in water to a considerable extent, even when the carbonic acid has been driven off. The best methods for dealing with the bi-carbonates of lime and magnesia in water is unquestionably the addition of some chemical to the water, which will combine with the carbonic acid forming an insoluble compound which is precipitated. The cheapest and best chemical for this purpose is lime. If lime is added to a water containing calcium and magnesium bi carbonates in sufficient quantity to combine with the whole of the loosely combined and free carbonic acid, the whole of the carbonates will be precipitated with the exception of about 1½ grains per gallon of calcium carbonate, which is a negligible quantity.

The following equations will make the reactions quite plain:—

$$\underset{\text{Insol.}}{CaCO_3} + CO_2 + H_2O \quad \underset{\text{Soluble.}}{Ca\,(HCO_3)_2}$$

$$\underset{\text{Soluble.}}{Ca\,(HCO_3)_2} + CaO \quad \underset{\text{Insol.}}{2Ca\,CO_3 + H_2O.}$$

In the case of magnesium bi carbonate, the corresponding equation is:—

$$Mg(HCO_3)_2 + CaO \quad CaCO_3 + MgCO_3 + H_2O.$$

But the magnesia would not thus be satisfactorily precipi tated, because normal magnesium carbonate is fairly soluble in water. To remove magnesia it must be further reduced to hydrate, which is practically insoluble.

The following equation indicates the reactions which take place in the case of magnesia:

$$MgCO_3 + CaO + H_2O \quad (OH)_2 + CaCO_3.$$

Hence bi carbonate of magnesia requires twice as much lime to deal with it as the equivalent quantity of bi carbonate of lime.

Caustic soda or barium hydrate may also be used for the removal of the carbonate hardness, but both these substances are very much more expensive, besides having other draw backs. Caustic soda should not be used unless there is sufficient calcium sulphate, chloride, or nitrate to use up the sodium carbonate which is produced by the interaction between the caustic soda and the bi-carbonate of lime.

$$Ca(HCO_3)_2 + 2NaOH = Na_2CO_3 + CaCO_3 = H_2O.$$

Caustic soda has also the disadvantage of being very dangerous to handle, and should an excess occur in the treated water it is very harmful to boiler fittings.

In the case of barium hydrate the reactions taking place are illustrated by the following equations:—

$$Ca(HCO_3)_2 + Ba(OH)_2 \quad CaCO_3 + BaCO_3 + H_2O.$$

Carbonate of barium is obtained and this in turn acts on the sulphate of calcium, if present, thus:—

$$BaCO_3 + CaSO_4 = BaSO_4 + CaCO_3$$

Barium hydrate should not, however, be used for water used for drinking purposes, as the salts of barium are very poisonous.

Calcium sulphate, calcium chloride, and calcium nitrate

* Abstract of lecture delivered before the Nottingham Engineering Society.

are most suitably and cheaply removed by means of soda ash, the reactions taking place being represented by the following equations:

$$CaSO_4 + Na_2CO_3 = Na_2SO_4 + CaCO_3.$$
$$CaCl_2 + Na_2CO_3 = 2\,NaCl + CaCO_3.$$
$$Ca(NO_3)_2 + Na_2CO_3 = CaCO_3 + 2\,NaNO_3.$$

Magnesium sulphate, magnesium chloride, and magnesium nitrate may be removed either by the use of caustic soda or lime and soda ash. In the case of caustic soda the reactions are:

$$MgSO_4 + 2\,NaOH = Mg(OH)_2 + Na_2SO_4$$
$$MgCl_2 + 2\,NaOH = Mg(OH)_2 + 2\,NaCl.$$
$$Mg(NO_3)_2 + 2\,NaOH = 2\,NaNO_3 + Mg(OH)_2.$$

and the reactions with lime and soda ash are represented by the following equations:

$$MgSO_4 + Ca(OH)_2 + Na_2CO_3 = Mg(OH)_2 + CaCO_3 + Na_2SO_4.$$
$$MgCl_2 + Ca(OH)_2 + Na_2CO_3 = Mg(OH)_2 + CaCO_3 + 2\,NaCl.$$
$$Mg(NO_3)_2 + Ca(OH)_2 + Na_2CO_3 = Mg(OH)_2 + CaCO_3 (2\,NaNO_3).$$

It will thus be seen that all the hardening salts present in water may be removed simply by the use of lime and soda ash. Acid waters are also amenable to the treatment of lime and soda.

The removal of grease and oil from water may be brought about either by mechanical or chemical means. The latter means would be better described, perhaps, as chemical and mechanical combined, as chemicals are added to the greasy water and these combine forming a colloidal precipitate, and this precipitate absorbs the oil particles in the water and carries the oil down mechanically with the precipitate. Oil or grease occurs in feed water in two conditions, being present either in comparatively large or comparatively small particles. Free oil may be defined as that which is present in particles of such size that their behaviour is controlled by the ordinary hydrostatic or gravimetric laws. The particles will consequently rise to the surface of the water in a moderate time or adhere to the sides of the containing vessel, or will aggregate in larger masses. They may be removed from the water mechanically by filtering through a medium of ordinary texture, such as filter paper, felt, or cloth.

Emulsified oil may be defined as that in which the particles are so minute they can no longer obey the ordinary laws, but are governed by the special laws which have been discovered to apply to finely-divided substances suspended in a fluid, in which the dimensions of the particles form a very important factor. Emulsified oil is readily recognised in the condensed water by the milky appearance it causes. The individual globules are quite inappreciable to the unaided eye, but they can be readily distinguished under a moderate power of the microscope. They are best seen and studied under a high power, such as is employed for bacteriological work, and will then be seen to be of varying size, some being no more than one 100,000th part of an inch in diameter. They are consequently incapable of removal by filtration through any ordinary medium, being themselves much smaller than the mesh of any material which could practically be employed. In this state the oil is very difficult to remove, but it may be accomplished by adding sulphate of alumina and carbonate of soda to the water, and the whole subjected to a thorough agitation. The precipitate which forms retains the whole of the oil. The precipitate is allowed a certain time to settle and the last traces filtered off, and the resulting water will be found to be quite free from all traces of oil.

Mechanical exhaust steam separators afford a partial solution to the problem of removal of oil from boiler feed-water. In these contrivances the steam is treated as such. A partial condensation is allowed to take place, and the steam is, so to speak, washed by the resulting water, which together with the oil accompanying it, is removed from the separator either continuously or at intervals. The different types of apparatus in use are of varying degrees of efficiency, and some remove a large proportion of the oil. I have never come across one, however, which has succeeded in effecting a complete removal of oil. Very extravagant claims have been made of the efficiency of some types of separator, but nevertheless it frequently happens that after the installation and trial they have to be replaced and supplemented by more effective apparatus.

Another method which has been employed for the aggregation of oil particles into a filterable condition consists in the passage of an electric current through the water. Iron electrodes are employed, and a precipitate is obtained containing oxide or hydrated oxide of iron. In general the resistance of condensed water is too high to permit of the passage of a sufficient current, and it is necessary to add hard water or some suitable salts to overcome this difficulty; after the water has been exposed to the action of the current it is filtered through a suitable medium.

Having indicated the various impurities found in water, the disastrous effects some of these impurities have on steam boilers, and the chemical reactions which may be brought about to remove these objectionable impurities, I propose to draw attention to a few industries in which the employment of soft water should be considered not only as a source of great economy, but as a real necessity.

Tannery work necessitates the employment of a huge quantity of water, both in the dehairing process and in the tan-pit. Proctor, in his "Principles of Leather Manufacture," says "Of all materials employed in tanning, none is of more indispensable importance than water, and its quality has undoubtedly great influence on tanning." The salts in solution in the water have a considerable influence on the results obtained. Before transforming the hides into leather, the hides are unhaired. The unhairing of the soft skins consists in loosening the bulbous roots of the hairs by saponifying the greasy matter secreted by the small hair glands. This is done with such an agent as quicklime, and the water used has a considerable effect on the operation. If the water contains a large proportion of calcium bi-carbonate, the excess of carbonic acid produces a precipitate of calcium carbonate, and this deposits in the dermic tissue. This deposit interferes with the absorption of the tannin in the cells of the hide and retards the tanning process. The carbonate of lime is also the cause of brown stains on the leather. In the tan pits the carbonate of lime is transformed into tannate of lime which oxidises rapidly in the air, and, according to Buchner, forms secondary products of tan oxylic and tan omelanic acids, giving a reddish-brown colouration to leather which decreases its market value. Permanent hardness is of little moment as regards the ordinary uses of the tannery, though it has considerable influence in some of the processes of dyeing, and acts very injuriously where soap is used for scouring, as in the washing of sheep skins, for wool mats. By forming tannic compounds, water containing lime and magnesia leads to loss in the tan-pits, therefore in preparing these extracts a soft water should invariably be used.

Many accidents in dye works, print works, and bleach works have their origin in the water used. Water containing organic matters may bring about the putrefaction of the extracts used, and prevent them from keeping. A water may make a good dye with one colouring matter, and a very bad one with another. Nevertheless, as a rule in dye works, as pure a water as possible should always be used. Aniline colours, such as magenta, the soluble blues, methyl violet, malachite green, and safranine, dissolve badly in calcareous waters. A heavy tar-like precipitate is formed which leads to poor shades and uneven dyeing. Although calcareous waters, as a rule, are unsuitable in dyeing and textile printing, on the other hand, when log-wood or weld is dyed in a mordant of iron or aluminium, the presence of the salts of lime is indispensable. This is an exception to the rule, however; in extracting the colouring matter from the dye woods, lime in the water is very harmful. In dyeing turkey-red or cochineal scarlet, which is done in an acid bath, their presence flattens the shade produced and wastes the colouring matter. Bismarck brown, an azo-colour, gives much darker shades in calcareous waters than when a soft water is used. Lime in the water is just as harmful in mordanting. It weakens the baths by precipitating the salts of aluminium and of iron. It decreases or neutralises the acidity of the bath and transforms the bichromates into neutral chromates. The presence of lime causes other troubles in madder dyeing. The carbonate of lime in the water very easily precipitates on the goods. It spots the whites and becomes the centre of attraction for colouring matter.

When calcareous waters are used, wools are imperfectly freed from grease and suint, an insoluble soap forms with the fatty matter in the wool and the metals of the alkaline earths.

and this is fixed on the fibres. As a result of this the dye liquor is irregularly absorbed. The stuff is unevenly dyed, and spotted in places, and much of the dyestuff in the bath is wasted. In washing woollen goods after dyeing, if calcareous waters are used they take a dull shade or gloss which is not natural, at the same time weakening the colours. In cloth bleaching the nature of the water used is of great importance, and to obtain good and regular results the works must be supplied with pure water. Calcareous waters are particularly harmful, as the compounds formed by the various dyes and the gummy matters are difficult to dissolve and adhere firmly to the fibre. Moreover, calcareous water is very wasteful of soap. A ferruginous water cannot be used at all in bleaching, as the iron forms salts with the soda dyes and the salts of lime and spots the cloth or yarn with yellow. In dye-houses and bleach works troubles often arise and goods are spotted when condenser water is used from the waste steam. When anti-scale compounds are used in the boiler, the water often contains these products which are carried off by the steam, either as they were introduced into the boiler or decomposed. Raw wool as it comes from the sheep's back contains a fatty matter secreted by the animal known as suint. This fat adheres strongly to the fibre, and can only be eliminated by a special treatment which is the preliminary process of the linen industry. Desuinting and degreasing wool need large quantities of water, and the composition of this has a considerable influence on the success of the operation, and is capable even of changing the nature of the fibre. When wool is washed with a hard water the permeability of the fibre is diminished, and this interferes with the regular fixation of the mordants and colouring matters, and consequently an uneven shade is produced in the dye bath. The process of degreasing wool is usually carried out with salts of potash, and if the waters used contain salts of lime, there is a great waste of soap. Soap is neutralised by the lime salts, and wastes its action on them until it has converted the whole into an insoluble soap. The calcareous insoluble soap thus formed is deposited in the fibre and adheres to it. Under these conditions the wool cannot be completely freed from grease, and trouble arises in every subsequent operation. Calcareous waters are also harmful in the preliminary treatment of cotton, silk, linen, and hemp.

Silk is composed of fibroine or pure fibre and a gummy matter which must be completely got rid of before the silk is dyed. Calcareous waters are unsuitable in reeling the silk from the cocoon, as the salts of lime precipitate, adhere closely to the fibre, and completely spoil the subsequent processes.

Waters which contain too large a quantity of the salts of calcium or of magnesium, lead to a waste of alkaline lyes in soap works. Soap or potash lye reacts on the calcium salts, precipitating them in the form of carbonate of calcium, an insoluble body which is harmful in the subsequent processes of soap making.

The laundry industry, which has developed very considerably of late, is interested in the highest possible degree in the question of water supply. If a hard water is used for laundry purposes, there will be an extravagant waste of soap resulting from the formation of insoluble salts of lime and magnesia at the expense of the soap in the washing machine.

In sugar works where animal charcoal is used in the clarification it must be washed with pure water. If salt water or calcareous water is used, the animal charcoal quickly loses its bleaching power, because of its property of absorbing saline substances. At the end of a short time it must be revived or replaced.

The method of extraction of the sugar from the beetroot by diffusion depends upon the phenomenon of osmosis produced between the water and the juice of the beetroot, the cell walls playing the part of dialyser. The salts contained in the water used must be taken into consideration, as by reason of the huge quantity it is necessary to employ, the proportion rapidly increases in the concentrated juice, interfering with the crystallisation of the sugar, and diminishing the yield. Water charged with the sulphates of lime and magnesia is harmful, as these salts retain a notable quantity of sugar in the mother liquor.

I think I have now said enough to show the enormous advantages to be gained by the employment of soft water, and I will now proceed to describe the various plants on the market for the treatment of hard waters on the commercial scale.

A few remarks here with reference to boiler compounds will probably not be out of place. There are now a very large number of these compounds on the market, most of which consist of caustic alkali, distinguished generally by the admixture of some more or less inert substance. These are sold under trade names at extremely high prices, and the results obtained are, if anything, mostly inferior to the results obtained by the use of plain alkali. The whole system of preventing the formation of scale by the introduction of substances into the boilers is essentially wrong. To start with, a boiler is meant for steam-raising purposes only, and not as a tank for carrying out a chemical process. Even supposing that the introduction of a boiler compound into a boiler does prevent the formation of a hard scale, it cannot prevent the deposition of all the scale-forming matter in the water, in the form of mud, and this is almost as bad as scale, especially in the case of water-tube boilers. The following translation of extracts from a report upon various boiler compositions made by a German chemico-technical institute are of interest. The investigations seem to cover most descriptions of such compositions as are in common use in this country.

No. 1 " is irrational and expensive, and people are to be emphatically warned against its use."

No. 2 " belongs to those secret remedies, by means of which the simplicity and credulity of possessors of steam boilers are clumsily turned to profit."

No. 3 " can only be employed upon the basis of an exact chemical analysis of the water in question. It does not belong to the class of universal anti-incrustation remedies, but rather can only cope with incrustation when applied in a rational manner."

No. 4 " when introduced into the boiler increases the amount of solid residue, and may easily give rise to disadvantages and dangers, especially if particles of it are projected by ebullition into the valves and other fittings of the boiler. People are therefore warned against the use of this so-called anti-incrustation remedy."

No. 5. " 35 kilos. of commercial caustic soda, which can be procured for 8s. 6d., will produce the same effect as 100 kilos. of No. 5, the price of which is from 68s. to 80s."

No. 6 " is a feebly alkaline vegetable juice, containing a very large proportion of water, with various salts, but no starch or dextrine. The action of this consists in grossly contaminating the boiler water with organic matter, by which means the agglomeration of the scale-forming matter into a hard scale is altogether irrational."

The same remark holds good for a vegetable extract No. 7, which is put on the market as an anti-incrustating remedy.

No. 8 also possesses the above-mentioned disadvantages.

No. 9 " with 65 kilos. of 98 per cent. soda ash costing 9s. the same effect is produced as with 100 kilos. of No. 9, which is sold for 50s."

No. 10. " This also consists of a thick vegetable extract containing tannin (katechu). The remarks under 7 and 8 apply equally to this."

These observations call for little comment, but it will be noticed that, with the exception of No. 3, the others are unreservedly condemned.

Practically all the plants on the market for the softening of water use the same materials, namely, lime and soda ash or caustic soda, their difference being in the mode of construction and the gear for proportioning the chemicals. This latter is the all-important point of a water-softening plant, as it is not only necessary to add lime and soda to the water to be softened, but the lime and soda must be added in definite proportions. Moreover, after the chemicals have been added to the water, the whole should be subjected to thorough mechanical agitation, as only in this way can absolutely uniform results be obtained. In addition to this, by thorough mechanical mixing the precipitate produced is rendered more granular, and in such a condition it settles more completely. Ample time should also be allowed for the chemical action to complete itself, and my experience has convinced me that it is impossible to obtain satisfactory results if less than three hours is allowed for the passage of the water through the plant. It is only after mixing and allowing a considerable settling time that the precipitated calcium carbonate begins

to separate out and settle. If the water is filtered before this separation has had time to take place, the finely divided precipitate passes through the filter, and precipitation takes place in the pipes and in the boilers, and the water is unable to be used for other industrial purposes. Moreover, this fine precipitate soon clogs the filters, necessitating their cleaning every fortnight or so. Another very important point is the removal of sludge. The precipitated hardening salts are deposited in the bottom of the main settling tank in the form of sludge, and it is absolutely necessary in order to get the best results that this should be done completely every day. There is only one method, applicable to all sizes of tanks, on the market for doing this, and that is by means of the Kennicott patent revolving sludge pipes. These pipes consist of two hollow arms, closed at one end and with a tapered slot cut right along the bottom of each arm. When the tank is sludged the valve is opened and the hollow arm caused to revolve slowly through the sludge by turning a handwheel. As the arms revolve the sludge is forced through the slots at the bottom and out through the main sludge pipe to the sump. In this way the sludge is collected from all over the bottom of the softener in much the same way as the vacuum cleaner does its work. So efficiently does this gear work that the main tanks of the Kennicott softeners have never to be opened for cleaning, and the Kennicott filters last, on an average, 12 months without renewing.

There is one method of softening lately put on the market which does not use lime, and this process I will therefore consider by itself first. This process has been introduced on the market as the Permutit process. The so-called Permutit is a sodium salt of silicic acid combined with aluminium, better known as sodium aluminium silicate. This substance may be produced artificially by melting together silica or quartz, alumina or kablin, and carbonate of soda. The melt is extracted with water and a granular substance is obtained containing:—

Silica	46	per cent.
Alumina	22	,,
Sodium Oxide	13·6	,,
and Water	18·4	,,
	100·0	,,

This substance is an artificial zeolite. Natural zeolites are common in rocks and soils as representing one of the stages of disintegration. They are hydrated silicates of alumina holding some earthy or alkaline base in combination. If water containing lime or magnesia salts in solution is passed through a bed of sodium aluminium silicate, the sodium in the permutit is replaced by the calcium or magnesium of the lime and magnesium salts and insoluble calcium or magnesium permutit is formed. Thus:—

$$Na_2Al_2Si_2O_8 + Ca\,(HCO_3)_2 = 2NaHCO_3 + Ca\,Al_2Si_2O_8.$$

$$Na_2Al_2Si_2O_8 + MgCo_3 = Na_2CO_3 + MgAl_2Si_2O_8$$

and the resulting water is perfectly soft. This is a very pretty process, but unfortunately it has one or two drawbacks which very materially affect its likelihood of becoming a commercial success. The chief drawbacks to the Permutit process are:—

(1) It is impossible to treat a carbonate water without leaving an excess of soda in the water.

(2) It is impossible to treat water containing any matter in suspension.

(3) The cost of treatment is far too high for the advantages gained.

(4) It is impossible to treat water hot.

(5) It is necessary to stop the plant for a considerable period in order to regenerate the Permutit.

When all the sodium in the Permutit has been replaced by calcium or magnesium, it is necessary to regenerate the Permutit. This is done by means of a solution of salt, and the reaction which takes place may be represented by the following equation:—

$$CaAl_2Si_2O_8 + 2NaCl = CaCl_2 + Na_2Al_2Si_2O_8.$$

This at first sight seems very simple and cheap. The regeneration, however, takes about 10 hours, and then water has to be passed through until all the calcium chloride has been washed away. This entails considerable time and a large waste of water. It will be noticed that for one molecule of calcium bi-carbonate, two molecules of sodium chloride have to be theoretically employed to regenerate the permutit. The process, however, strictly follows the laws of mass action and as calcium more readily combines with permutit than sodium, it follows that for the regeneration more salt is necessary than is indicated theoretically by the above equation. In practice, at least four times as much salt is required as is theoretically necessary. We can therefore make comparison between the cost of treatment with permutit and the cost of treatment with lime. Taking a water containing temporary hardness only, where one ton of lime would be required for softening, eight tons of salt would have to be used to regenerate the permutit. As the salt required costs at least 25s. per ton, and the lime costs only about 15s., we have the cost of treatment by permutit £10, compared with 15s. for lime treatment, or over 13 times as much. In addition to this extra cost the permutit process has the objection that it leaves soda in the treated water and leaves the amount of total solids in the treated water the same, whereas lime actually reduces the quantity of dissolved solids proportional to the amount of temporary hardness in the water. The lime treatment, moreover, destroys about 98 per cent. of the bacteria found in the water.

The best-known plants in the market for softening water by the lime and soda process are the following: Archbutt Deeley (made by Messrs. Mather & Platt,), Lassen & Hjort, Paterson, Royles (Reisart system), Bobys, and Kennicott water softener.

HEAT TREATING PLANT IN A RAILROAD SHOP.

FOR the heat treatment of locomotive parts, such as side rods, valve motion parts, &c., the Pennsylvania Railroad is installing in its Juniata shops a number of special furnaces, several of which are described in "The Railway and Engineering Review." The plant will include a vertical cylindrical

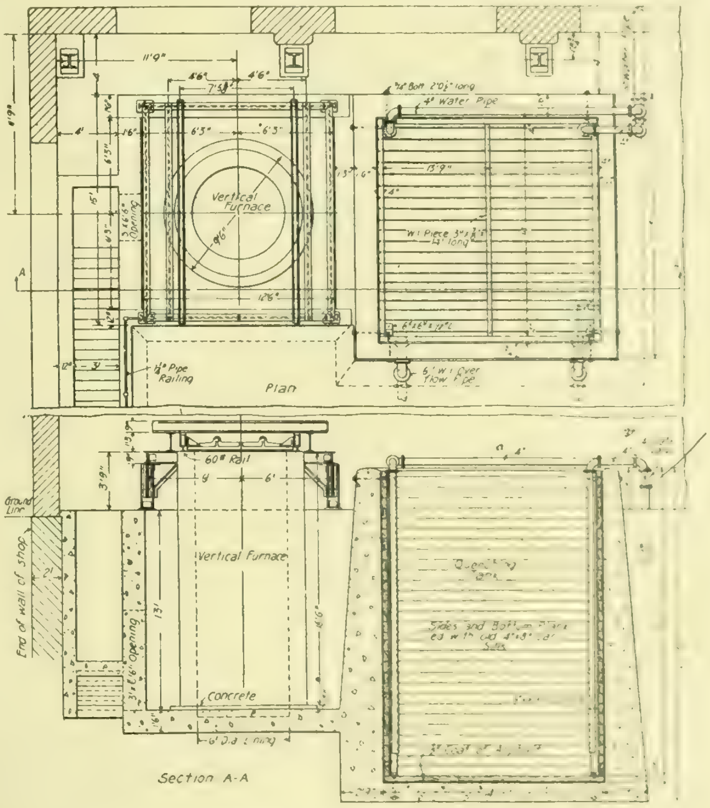


FIG. 1. ARRANGEMENT OF CYLINDRICAL ROD FURNACE AND QUENCHING TANK.

gas-fired furnace 6ft. inside diam. by 16ft. 6in. deep, in conjunction with a quenching tank 13ft. 9in. by 14ft. by 20ft. deep; a "car bottom" type furnace with a heating chamber, 7ft. wide, 14ft. long, and 2½ft. high, this furnace using the same quenching tank as the cylindrical furnace; a 7ft. by 4ft. 3in. by 12in. gas-fired muffle furnace for smaller parts with water and oil baths adjacent; and a tempering plant for tools, consisting of a small gas furnace, an electric furnace, and a lead pot, quenching tanks, &c.

The vertical furnace and quenching tank are shown in detail in Fig. 1. The furnace is contained in a concrete-lined pit about 12ft. square and 13ft. deep; one side of this pit being common to the quenching tank. The quenching tank is lined throughout with old 4in. by 8in. car sills, which serve to protect the concrete both from the effects of heat and impact from heavy objects suspended therein. Intervening between the sills and the concrete is a ½in. coat of asphaltum. Water is admitted to the tank through two 4in. pipes discharging near the bottom corners of the tank on one side, while two 6in. pipes near the top corners on the opposite side of the tank take care of the overflow. The furnace itself is a cylindrical brick structure 8ft. outside diam. and 16ft. 6in. high, having a 4in. firebrick lining, leaving an inside diameter of 6ft. The top is covered by means of a pair of roller-mounted doors running on 60 lb. rails, laid across the top of the furnace. Firing is by means of fuel oil, the blast being admitted tangentially at eight different points and at four separate levels. The burners are controlled by means of operating levers extending up to each of four control platforms around the circumference of the furnace near the top. Four ladders down the sides of the furnace are likewise provided in close proximity to the four platforms respectively, so that

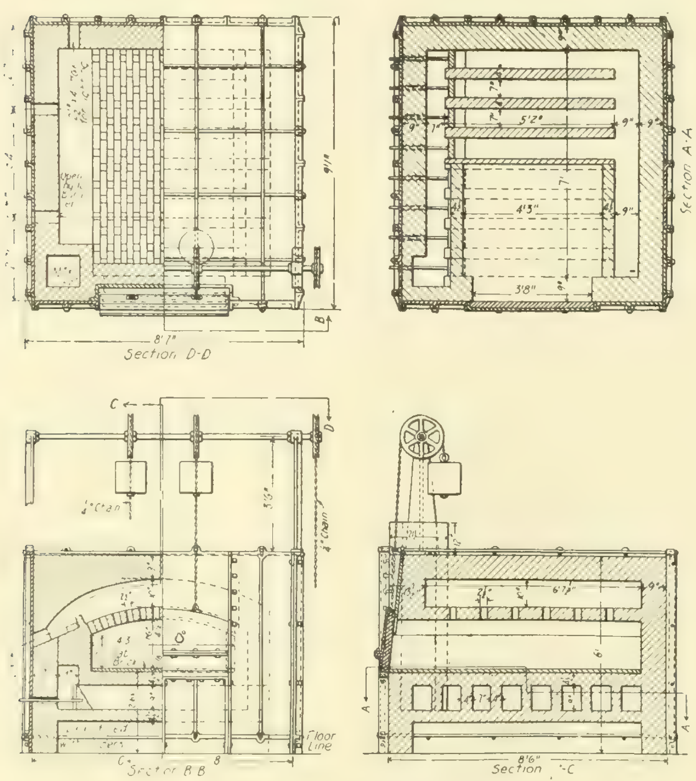


FIG. 2.—OIL-FIRED MUFFLE FURNACE.

possible derangement of the burners or the control levers can be readily attended to. The pit is also accessible by means of a concrete stairway outside the pit and adjacent to the end wall of the building.

The "car bottom" type furnace will open at the bottom, its floor being separate and mounted on wheels, virtually forming a flat car with steel trucks and underframe and with a firebrick floor, which forms the bottom of the furnace. This car can be loaded with parts to be treated and then pushed into the furnace on a track provided for the purpose. Space has been reserved in the layout for a second furnace of this type should its installation at a later date be found desirable.

The oil-fired muffle furnace, shown in Fig. 2, is of a type developed a few years ago by the mechanical department of the Pennsylvania Railroad in its efforts to secure an efficient furnace for extensive experiments in heat treatment of steel, reclamation of springs, &c. Its construction is clearly shown in the illustration. It will be used largely in experimental work and in the treatment of smaller locomotive parts. The electric furnace and the small gas furnace provided for in the general layout will be used for tempering tools, for experimental purposes, &c.

HUMPHREY & RUSDELL'S INTERNAL-COMBUSTION ENGINES.

INTERNAL-COMBUSTION engines are known in which a body of liquid reciprocates within the combustion chamber or cylinder, either alone in the form of a column of liquid or in conjunction with a moving solid piston. One of the advantages of engines of this kind is that the engine is internally cooled by the liquid. When, however, the engine has no solid moving piston and is to operate beyond a certain speed, this advantage is more or less counteracted by the liability of the liquid to splash. If, for example, during a compression stroke the liquid is moving vertically upwards and its rate of retardation exceeds 32ft. per sec. per sec., then particles which may become detached from the surface of the liquid will move on into the gases. The accompanying illustrations show a number of designs of internal-combustion engines and pumps patented by Mr. H. A. Humphrey, 38, Victoria Street, Westminster, London, and Mr. W. J. Rusdell, in which the advantage of internal cooling by liquid is retained and the aforesaid counteracting disadvantage avoided by providing within the combustion chamber or cylinder a body of liquid between which and the cylinder walls there is relative movement, so that the walls are cooled, which body is stationary or has less movement than the relative movement between the cylinder and the piston.

The design shown diagrammatically in Fig. 1 is for the production of motive power, and comprises a moving combus-

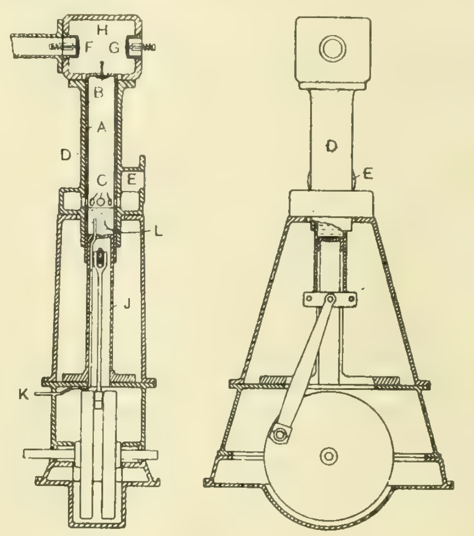


FIG. 1.

tion chamber or cylinder A having at its closed top end an inlet valve B for combustible constituents and lower down exhaust ports C which are shown registering with other ports in a stationary cylinder D, so that the exhaust gases may pass away at the exit E. The cylinder A is a sliding fit in cylinder D, and fixed to the top of the latter is an admission box fitted with a gas inlet valve F and an air inlet valve G. The cylinder A slides over the stationary piston J, which is shown slotted to permit the connecting rod to pass through all working positions and so transmit power to the engine shaft. Cooling water for the cylinder is supplied through pipe K so that the body of water L may be constantly renewed, the surplus water passing out through the exhaust ports C.

The action of the apparatus is as follows: On the downward stroke of cylinder A gas is drawn through valve F and air through valve G into the admission box H, and at the end of this stroke valves F, G are closed by their springs. On the upward stroke of cylinder A the combustible mixture contained in H is compressed while the products of combustion in cylinder A are expanding. Towards the end of the upstroke exhaust gases escape from A through port C and exit E and the fresh combustible charge enters through valve B, displacing the burnt products. The valve B may be fitted with a light spring so that it closes when the pressures on the two sides are nearly equal and the flywheel effect is now relied upon to draw down the cylinder A and so compress the fresh charge contained therein until at the point of maximum compression the charge is fired to produce an upward working stroke. It will be observed that in moving downwards the

cylinder walls come in contact with the stationary cooling liquid L.

Fig. 2 shows a 2-stroke cycle pump in which the moving cylinder A, which slides over the stationary piston J, is attached to a pump piston M of greater diameter and sliding in a pump cylinder N. There are fitted inlet valves O and outlet valves P for liquid, and the annular space Q, formed by an inverted bell-shaped casting in the cover of cylinder N, may contain air. In the present example the apparatus operates on the 2-stroke cycle as described with reference to

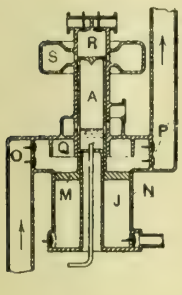


FIG. 2.

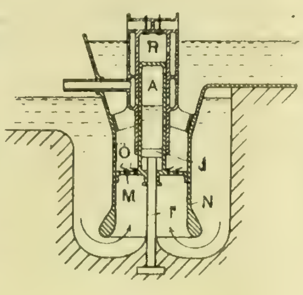


FIG. 3.

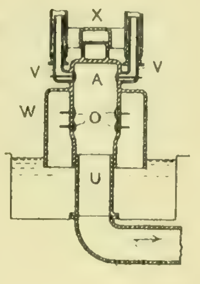


FIG. 4.

Fig. 1, but the space into which combustible mixture is compressed comprises a relatively small chamber R and a relatively large chamber S, so that the small chamber may constitute an elastic cushion to prevent an undue movement of cylinder A in the upward direction. The space in cylinder N below the piston M may serve as an elastic cushion for storing energy to assist the upward movement of cylinder A, or the space below piston M may be fitted with suitable valves for the inlet and discharge of liquid so that the pump may then be double acting. Air compressed in the space Q during an upstroke may by its expansion assist in producing a downstroke.

Fig. 3 shows a 2-stroke cycle single-acting pump in which the inertia of the mass of water set in motion on the working stroke plays an important part in the operation, since its momentum is used to produce a prolonged movement. Instead of the moving cylinder A sliding over a hollow stationary piston as in previous examples there is a stationary piston J rigidly supported by a rod T passing through a gland formed in the piston M and the latter is fitted with a number of inlet valves O for liquid. On an upward working stroke the valves O are closed and the water in cylinder N and in the approaches and discharge thereto is set in motion. The proportions of the various parts and of their masses are such that the liquid last mentioned is still moving when the cylinder A moves downwards and the latter with its differential piston may complete its downstroke under the action of gravity and energy stored in the elastic cushion in the top of R to compress a new charge in chamber A. Preferably, when the maximum compression pressure is attained the liquid in cylinder N comes substantially to rest. Valves O close and the ignition of the fresh charge starts a new cycle. The cooling water in chamber A may be introduced through rod T.

Fig. 4 shows a 4-stroke cycle pump in which there is a constant flow of liquid in discharge pipe U, the movement being in the direction of the arrow and the pipe being made long enough so that the liquid contained in it may have the required mass. In this case instead of a stationary piston the liquid in U serves as a buttress against which the pressure of the ignited gases acts when the moving cylinder A is raised on the working stroke. The mass of cylinder A is augmented by that of the sliding pipes V, and by the inverted bell W and the liquid contained in this bell. These masses acting downwards under the action of gravity are of such total weight that they produce a pressure which balances the static head against which the liquid is raised. The admission and exhaust valves situated in pipes V respectively are so controlled that they are opened and closed at the correct times to give the required 4-stroke cycle. The pipes V slide respectively in stationary pipes, and in the bridge connecting these two there is a space X which constitutes an elastic cushion for the purpose of limiting the upward movement of cylinder A. The inlet valves O for liquid are shown in the walls of cylinder A, and it will be understood that the movement of the liquid in the pipe U varies in velocity without change in its direction of flow.

Fig. 5 is in many respects similar to Fig. 1, but whereas the latter is a 2-stroke single-acting engine, Fig. 5 shows a 2-stroke double-acting engine. A is the moving cylinder and J the fixed piston, but in the present case combustion occurs alternately above and below this piston. There is one set of exhaust ports C in cylinder A and two sets of exhaust ports in the cylinder D. Of these sets one is shown as registering with the ports C and the other set is shown dotted at X. Cylinder A is provided with an inlet valve for combustible mixture at the top and inlet valves R at the bottom. Cylinder D is fitted with two sets of air valves F, while gas or combustible mixture enters at pipes Y, which are in communication with receivers Z respectively, these being fitted with non-return inlet valves for gas or mixture as shown. Projections from the moving cylinder A carry the crosshead pins. The stationary cylinder D is slotted in the middle to accommodate the movement of the projections and crosshead pins so that the power can be transmitted through connecting rod to the crank shaft in the manner shown. The arrangements for introducing air and mixture shown are such that air first enters cylinder A to scavenge out burnt products and then gas or mixture enters subsequently to be compressed and ignited. In the postion of the parts as shown there will be a compressed combustible charge in cylinder A below the piston J, valves R will be shut and below these valves in cylinder D there will be in the upper part air and in the lower part combustible mixture or gas. In the upper part of cylinder A exhaust will have occurred and the combustible charge will have been introduced ready to be compressed on the downward stroke of cylinder A.

Fig. 6 shows a single-acting 2-stroke cycle pump in which the air for scavenging and the gas are compressed and supplied separately to the moving cylinder A. Air may be compressed in the space H and supplied through valve B, and gas or mixture may be compressed in the annular space Q and supplied through the receiver R and past the non-return valve S to enter cylinder A at port T. The space U below the fixed piston J contains an elastic cushion to prevent undue movement of the moving cylinder on its upward stroke and may store energy for assisting the weight of the reciprocating parts in producing a downward stroke. The liquid to be pumped enters at V, passes through the stationary suction valves O and through the valves P in the moving piston M to be discharged at W. Liquid will be delivered through pipe W on both upward and downward strokes, and if the area of

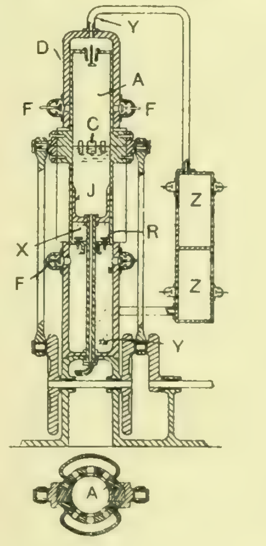


FIG. 5.

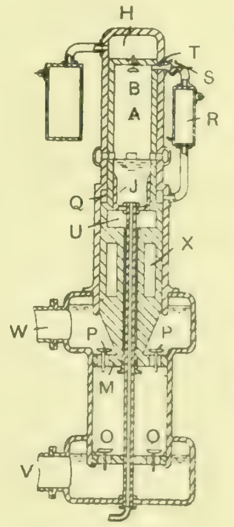


FIG. 6.



FIG. 7.

piston M is twice the area of the piston X equal amounts of liquid will be thus delivered on the upward and downward strokes.

The mode of igniting the combustible charges may be effected in several ways. One arrangement is shown in Fig. 7, in which the sparking plug projects in the top of the moving cylinder A, and the wire for conveying the electric current is carried to the plug through a tube screwed into the top of cylinder A and reciprocates with it, moving in a gland

in the top of cylinder D. The cooling water which is supplied for cooling the walls of the combustion cylinder may be supplied under pressure sufficient to ensure its introduction, and the surplus may be drained off through the exhaust gas ports, but it is generally advisable that a non-return valve should be inserted in the pipe supplying the cooling liquid to prevent a reverse flow when the pressure in cylinder A rises.

CONTINUOUS FEEDING ELEVATORS.

IN a paper recently read before the Junior Institution of Engineers, Mr. T. C. Morewood dealt with the various types of continuous feeding elevators. The swing tray vertical elevator consists of two endless chains, running over top and bottom pairs of sprocket wheels, the top pair keyed to a shaft, and the bottom pair running in adjustable bearings. At intervals round each chain are attachment pins, from which depend arms carrying the trays, so that they swing between each chain and hang level; these trays are in the form of a grid with cantilever arms projecting from a centre bar, and designed so that at the top they pass through a fixed set of arms, on which is placed the case to be lifted. Discharge is thus on the downward side on to fixed arms, usually set at any angle and mounted with small rollers so that the case runs off clear. These discharging arms can be hinged and swung clear to let the case descend to next floor. This type of elevator can be made automatic, loading being done by means of a timing device so that the case is stopped and only allowed to run on to the loading grid when it is clear of one of the swing trays. Running continuous, it delivers about 300 cases per hour. The fixed vertical tray elevator is cheaper to build. It usually has two chains and sprocket wheels, but the carrying trays are rigid arms, standing out from the chains. It can be made to pick up, but cannot be made to automatically deliver, except for bundles which will stand being thrown over, and these only on top floor. The slat type of inclined elevator consists of two endless chains, running in guides, with slats between, forming an endless band. The guides can be turned over at the top and bottom so that the foot and head of the elevator becomes horizontal, giving smooth loading and delivery points. Small cross angles are fastened to the slats every 3ft. or so, and guard rails are fitted on either side. Such an elevator can load and deliver automatically from or on to a conveyer; it will take all shapes or boxes whose height is not more than their length; it uses little power, needs no attention, and will handle an astonishing number of goods. This type of elevator cannot be worked at much of an angle, usually only 30°. The claw type of inclined elevator can work up to, say, 60° angle. The cases are carried on roller carriers running up an incline and fitted with claws at the back, which are long enough to prevent the cases slipping at the steep angle and are arranged to pass through a discharging plate at top; the elevator is automatic in delivery but not in loading; will take all sizes of cases, but the speed is slow. The drag type can be made both automatic in loading and delivery, is fairly cheap, and will work at any reasonable angle. Lifting is done by drags, between the two sets of endless chains. As the boxes run on at the foot from the conveyer, the bar coming round the bottom wheels will sometimes get under the box instead of behind it, in which case it is stopped by some retarding device and is held while the bar is dragged from under it, the next bar taking it up. The bar is close down to the track, in order not to tilt box too much on coming on it. Immediately the box begins to ascend, the bar rises in order to avoid the box falling backwards, and it is for this reason the path followed by chains and lifting bars leave the track and only join it again at the point of delivery at the top. The drag type will deal with 1,000 cases per hour. In conclusion, Mr. Morewood thought that in these days of increasing cost of labour and ever-growing trade, there was a great future for this type of labour-saving device.

Personal.—The General Committee of Lloyd's Register of Shipping has appointed Mr. Westcott S. Abell, Professor of Naval Architecture at Liverpool University, to succeed the late Dr. S. J. P. Thearle in the office of Chief Ship Surveyor to the society. Mr. Charles Buchanan, who was Dr. Thearle's senior assistant, has at the same time been promoted to the position of principal of the Chief Ship Surveyor's staff.

METALS AND ALLOYS USED FOR DIE CASTINGS.

BY E. F. LAKE.

DURING the last decade numerous processes have been devised for the separation of many elements from the combinations in which they occur. While the existence of these elements has been known for nearly a century, methods of separation to make them commercially available have been developed only in recent years. The properties of these elements have been carefully investigated and a number are being employed as alloying material. Several have been found useful for increasing the tensile strength, wearing qualities, resistance to strains, and lightness of alloys that can be cast in metal moulds and these have been utilised for die-castings.

TABLE I.—*Composition of Lead Base Alloys that Can be Used for Die Castings.*

Trade Name	Lead per cent	Antimony per cent	Tin per cent
Electrotype	93	4	3
Russian railroad car	90	8	2
Ordinary bearing	87	7	6
Antimonial lead	87	13	...
Jacoby metal	85	10	5
Linotype	83	12	5
Antimonial lead	80	20	...
Magnolia	80	15	5
Bearing	80	10	10
Railroad bearing	75	15	10
Monotype	74	18	8
Standard white metal	71	24	5
Graphite metal	68	17	15
Railroad bearing	65	25	10
Railroad bearing	60	20	20
Standard type	58	26	15*

* 1 per cent. of copper also added.

These alloys may be divided into three classes, as follows: Alloys with a lead base; alloys with a zinc base; and alloys with a tin base. For the various uses to which die-castings may be applied, the other ingredients of these alloys may be any of the following: Antimony, bismuth, cadmium, copper, aluminium, nickel, silver, and iron. Recently boron, in the form of boron-copper, has been used. The iron is present as an impurity only and in minute quantity, as a small percentage of this metal would raise the melting point of the alloy, and no means have yet been found for making die-casting a commercial success from alloys whose melting temperature is much over 1,000° Fah.

Bronze, cast iron, steel, and some of the new and rare metals have been tried for making the moulds for die-castings. None of these, however, gave satisfactory service, particularly when the melting temperature exceeded 1,000° Fah. Special alloy steels have been found the most suitable for the dies, and are always used for high-grade castings. Bronze warps when used for dies, the castings becoming deformed. Cast-iron moulds flake and are easily chipped or broken. Steel begins to oxidise when the temperature is raised to about 1,400° Fah., and particles of the steel adhere to the castings.

The metals or alloys used for die-castings must possess a low point of fusion, but the lower the point of fusion, the weaker will be the metal or alloy, and it will be less able to withstand heavy stresses. Parts that are subjected to severe service should never be die-cast. The alloys with a lead base are the most numerous, as they have the lowest melting points and hence are the easiest to cast. When properly alloyed, the molten metal will flow freely into the most minute depressions in the mould, and intricate and delicate castings, therefore, can be made by this process. Lead-base alloys have the lowest physical properties of any of the alloys used for die-casting, and, therefore, cannot be used for castings subjected to severe service. Lead has been used in nearly all proportions up to 93 per cent., and it nearly always is alloyed with antimony and tin. Comparatively large percentages of antimony are used to overcome the excessive shrinkage of lead. Usually this varies from 10 to 25 per cent. The tin stiffens and strengthens the lead base alloy and usually is added in amounts varying from 5 to 20 per cent.

The compositions of lead-base alloys used extensively for die-castings are given in Table I. Many other combinations can be made, but these indicate the nature of these alloys.

They constitute the type and bearing metals and some of the solders that have been used for centuries, and yet some of these have been exploited as special, secret compositions made especially for die-castings. Lead has a high lustre, is bluish-grey in colour, possesses high malleability and ductility, low tenacity, and a dense grain. Its melting point is 621° Fah. Two or more pieces can be welded together by pressure alone, or if finely divided it can be pressed into a solid mass. It can be forced easily through small apertures to form various intricate shapes, as well as tubes and pipes of various forms. These properties make it specially useful for casting under pressure in metal moulds, but its physical properties are so low that other elements must be added to increase its strength. The density of lead, however, is decreased by the addition of other metals. Zinc cannot be alloyed successfully with lead, as it enters into solution with this metal only to a limited extent. These two elements can be made to enter into complete solution by heating to approximately 1,700° Fah., but when cooled slowly they again segregate. The oftener they are heated and cooled, the greater will be the segregation, and this will be increased by slow cooling. If it were possible to suddenly cool such an alloy from 1,700° to atmospheric temperatures, the zinc and lead could be held in solution. Therefore, any desirable properties that zinc might add to lead are nullified by the process employed in making die-castings, and such an alloy is useless for this purpose. Tin, therefore, must be used in place of zinc.

TABLE II.—*Zinc-Base Alloys Used for Die-moulded Castings.*

Zinc. per cent.	Tin. per cent.	Copper. per cent.	Antimony. per cent	Aluminium. per cent	Lead. per cent.
92·6	3·5	2·0	1·5	0·4*	...
92·0	...	7·0	1·0	...	...
90·0	...	5·0	...	5·0	...
89·0	1·0	6·0	1·0	3·0	...
88·5	...	4·5	...	2·5*	†
88·0	5·5	5·0	1·5	...	..
87·5	...	6·5	...	6·0	...
87·0	10·0	3·0	...	...	...
86·0	...	10·0	...	4·0	...
85·0	5·0	5·0	...	5·0	...
85·0	...	5·0	10·0	...	...
84·0	9·9	4·0	1·0	1·0*	1·1
83·0	5·0	10·0	...	2·0	...
82·0	6·0	1·5	0·5	*	10·0
82·0	6·5	5·0	...	...	6·5
79·0	11·0	6·0	4·0	...	...
76·0	17·5	5·0	1·5	*	...
47·0	31·0	20·0	...	2·0	...
74·0	15·0	5·0	...	6·0	...
74·0	12·0	11·0	...	3·0	...
73·0	19·0	5·0	2·0	1·0	...

* By analysis † Phosphor copper 4·5

Tin melts at a temperature of 450° Fah. It is a highly crystalline metal, that is, it is malleable and ductile and possesses high tenacity. As lead is non-crystalline and has comparatively low tenacity, tin forms a valuable alloying material. The tin hardens and increases the tenacity and toughness of the lead, and the lead increases the malleability and ductility of the tin. They are melted easily and combine in all percentages. The alloy shrinks less on cooling than either metal cast by itself. An alloy containing three parts tin and one part lead has a melting temperature 75° less than that of pure lead and 250° below that of pure tin. Increasing the percentage of either element in this alloy, increases the melting temperature in like proportions, until it reaches the melting temperature of the pure lead or tin when either of the other elements has been eliminated. The higher the percentage of tin, the smoother and brighter will be the surface of the die-castings, as it causes the alloy to flow or spread over the surface of the steel mould much better than when only a small percentage of tin is used.

Antimony expands when freezing into a solid from the liquid state, while nearly all other metals shrink. Antimony, therefore, is used in nearly all die-casting alloys to overcome their shrinkage. It melts at 1,166° Fah., and has a high metallic lustre of a silvery-white colour. It is hard and brittle and hence imparts hardness to lead or lead-tin alloys, at the same time decreasing their shrinkage. The zinc-base alloys require only from 1 to 2 per cent. of antimony, as the zinc has the proper degree of hardness and does not shrink as much as lead. In the lead base alloys, where both hardness and non-shrinking properties are desired, the antimony is sometimes increased as high as 25 per cent. It expands lead in proportion to the amount used, until the antimony is raised to 13 per cent. From this point the expansion declines until 35 per cent. of antimony is used; from 35 to 50 per cent. expansion increases, but from the latter point it again declines, but increases as the pure antimony is approached. The eutectic alloy contains 13 per cent. of antimony and 87 per cent. of lead, and its melting temperature is 443° Fah. This is 178° below the melting point of lead and 723° below that of antimony. Although antimony melts at a point above that at which die castings can be made successfully, the alloys in which it is used melt considerably below that point. The maximum hardness is imparted to lead with 17·3 per cent. of antimony. From this percentage it declines gradually until 80 per cent. of antimony is reached, when it increases rapidly until the hardness of pure antimony is attained. The maximum hardness of antimony is more than four times that of pure lead.

When making die-castings the metal is forced into the moulds under pressure, and this has a tendency to further increase the shrinkage. If castings are to be made within 0·005in. of the correct size, thereby eliminating machining, it is essential that the alloy completely fills the mould when the casting is cold. Therefore, the expanding properties of some such element as antimony must be used. Bismuth possesses this property to a greater degree than antimony. It also has a lower melting point, namely, 518° Fah. It requires only about one-half as much bismuth to accomplish the same results as antimony, and its melting point is well below the maximum for die-castings. Bismuth, therefore, is used sometimes, but it costs more than 20 times as much as antimony and for this reason is not generally employed.

Bismuth has a bright, metallic lustre of a greyish-white colour, slightly tinted with pink, and is very hard. It combines with tin in all proportions and increases its hardness, lustre, and fusibility. Up to 25 per cent. of bismuth, the alloy is ductile, but this decreases with higher percentages, and when 25 per cent. of bismuth is used the alloy can be pulverised. Bismuth can be used in small percentages with tin, but when lead is added to these metals it destroys many of the properties desired in die castings. This is due to the fact that lead does not combine with the bismuth and is liable to segregate when the alloy is cooling. Bismuth also lowers the melting point too much to be useful for anything but solders. One alloy of these three elements melts at 300° Fah.

The zinc base alloys are best adapted to die casting work and probably are the strongest of the white metal alloys for die-casting parts. They seldom contain lead except as an impurity, although occasionally a special anti frictional alloy is used that contains from 5 to 12 per cent. of this metal. The tin content rarely exceeds 15 per cent., but when a comparatively high copper mixture is desired, the percentage of tin must be sufficiently high to neutralise the high melting point of the copper and to overcome some of its bad casting properties. With 20 per cent. of copper about 30 per cent. of tin must be used. This will give the castings a yellowish colour, but they are not as strong as those with a lower copper and tin content. The highest tensile strength can be obtained by keeping both the copper and tin between 2 and 5 per cent. This is due to the fact that tin and zinc do not combine readily and the zinc is liable to segregate. A tin-zinc alloy is harder and less malleable than tin, softer than zinc, and more crystalline than both. The facets of crystallisation of tin-zinc alloys have a lustre similar to graphite. Small percentages of aluminium often are used to purify and strengthen die casting alloys, but high percentages increase the melting point too high. Aluminium also oxidises so rapidly that castings with a smooth surface and free from dross are difficult to produce. Some zinc base alloys that have been used successfully are given in Table II.

Zinc melts at 786° Fah., and has a bright, metallic lustre of a bluish-white colour. It is hard, brittle, and highly crystalline, but when cast near the solidifying point it is tougher, more malleable, and stronger than when cast at higher temperatures. Hence it is necessary to add other elements to increase its strength and toughness. Copper toughens zinc, but high percentages of this metal cannot be used and for this reason other alloys are added. Toughness is

obtained only at a sacrifice of hardness, and the additions of zinc and other metals must be governed by the uses to which the die-castings are to be put. If great hardness is desired, alloys with the higher zinc content are best, but when toughness is desired, the zinc percentages must be lowered in proportion to the amount of toughness required.

Copper backs the zinc crystals and thus, to a large extent, overcomes the crystalline nature of the zinc, but it does not add strength to any extent. Tin will add strength and toughness to this combination and hence it is nearly always used with them. Sometimes the tin is omitted and from 3 to 6 per cent. of aluminium is employed. Silver possesses high tenacity and has been added frequently to overcome brittleness, but it is too expensive for most commercial castings. Aluminium imparts stiffness and fluidity to zinc-copper alloys and excels tin in this respect. Three per cent. of aluminium added to 10 of copper and 87 per cent. of zinc will increase the strength five-fold. Phosphorus also adds strength and increases the fluidity. Nickel increases the strength and elasticity of these alloys, but its melting point is so high that it can be used only in very small doses.

The tin-base alloys are best adapted to bearing mixtures. An excellent alloy follows: Tin, 65 per cent.; zinc, 29 per cent.; copper, 4·5 per cent.; and antimony, 1·5 per cent. This alloy is termed a white bronze. Parsons white bronze contains 56·5 per cent. of tin, 38·5 per cent. zinc, 2·5 per cent. copper, 1·5 per cent. antimony, 0·5 per cent. of lead, and 0·5 per cent. of aluminium. The lead doubtless is an impurity. These alloys are used extensively for die-cast bearings, although numerous variations from these mixtures also are employed.

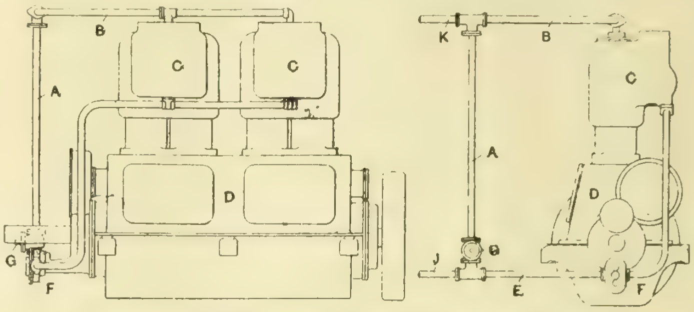
Numerous elements for die-casting mixtures also are being investigated, particularly those that will increase the physical properties. The latest of these is boron. An alloy is recommended for die-casting that contains 80 per cent. of lead, 19·75 per cent. of boron-copper, and 0·25 per cent. of antimony. It is claimed that this is tough, hard, and equal to babbitt metal. Its melting point is 900° Fah. Titanium also is being experimented with, and as this element removes oxygen and nitrogen it should prove exceedingly beneficial. Magnesium, sodium, and calcium are being tried for the production of alloys with low specific gravities, but no combination has yet been found that can be successfully cast in die-moulds under pressure. Thallium, tallurium, and cadmium are metals with low fusing points, but have not proved successful in die-casting mixtures.

The great objection to many die-castings is that they are porous and spongy in the centre, even though they may have a smooth, sound exterior surface. If an alloy could be produced that would be solid, homogeneous, and fine-grained throughout the cast part, or if the moulding methods could be improved so that this result could be obtained, the strength of the castings would be greatly increased and their uses would be greatly multiplied and extended commercially.—"The Foundry."

COOLING OF INTERNAL-COMBUSTION ENGINES.

THE arrangements ordinarily used for cooling the cylinders of internal combustion engines for marine purposes, consist of a pump delivering water to the jackets of the various cylinders from which it is discharged overboard. The pump may deliver separately to the jacket of each cylinder, or to all of them collectively, but in either case when the water supply is reduced in quantity, with a view to allowing the cylinders to remain at a comparatively high temperature, in order to ensure satisfactory combustion and good working, there is always the danger that some part of the cylinder jacket or system may be short of water, with the result that while the cylinder or system will be too cool in one part, steam will be generated in another, which may have most disastrous results, often resulting in a large deposit in the water jackets, which cause the cylinders to overheat and crack. The accompanying illustrations show an arrangement, specially applicable to marine motors, whereby, where a practically unlimited supply of cooling water is available, a proportion of water, depending upon the rate of working of the motor, is continually added to and rejected from the system, the water proportion being definitely predetermined by adjusting a valve.

The arrangement, which is the invention of Messrs. John I. Thornycroft & Co., Ltd., Caxton House, Westminster, London, S.W., is shown diagrammatically in the accompanying illustrations. A pipe A is shown as connecting the outlet pipe B or delivery end of the circulating system, including the jackets C. of the multi-cylinder engine D to the suction pipe E of the circulating pump F, a hand-operated valve G being placed in the connecting pipe A. The inlet end portion J of the suction pipe E beyond the pipe A which receives water



ARRANGEMENT FOR COOLING INTERNAL-COMBUSTION ENGINES.

from the sea, may be provided with a valve, say the usual sea-cock. By means of the valve G the amount of water passing from the delivery pipe B back to the suction of the pump F and the amount of additional water supplied through the pipe J to the circulating system and allowed to flow off through the outer end portion K of the delivery pipe B into the sea, and therefore the temperature of the water circulating through the jackets C of the engine, can be easily regulated to suit requirements.

PULVERISED COAL IN METALLURGICAL FURNACES.*

BY JAMES LORD.

ABOUT 10 years ago, the American Iron and Steel Manufacturing Company, noting the use of pulverised coal in the large furnaces of the cement industry, commenced the experimental use of this fuel in metallurgical furnaces. From the first it was apparent that its economical use depended upon the absolute control of the feed by the burner. This having been accomplished, we have applied it to over 100 furnaces of various types, such as those for puddling and heating, and of smaller sizes for re-heating nut, bolt, and spike bars.

It has proved to be a commercial success for all these purposes, and the experience of ourselves and of others working along similar lines shows that it can be used with equal economy for basic open-hearth steel furnaces, either with or without checker work. Our experience in the use of this fuel over a number of years has been so satisfactory and so economical that we are now largely increasing our installation, and are about to apply it to open-hearth steel furnaces.

Success in the use of this fuel requires: (1) That both the free and combined moisture be expelled by artificial heat down to 0·5 per cent. (2) That it be pulverised so that 95 per cent. will pass through a sieve of 100 meshes to the square inch. Over 80 per cent. that we pulverise will pass through a 200-mesh sieve. (3) The delivery to the furnace must be controlled by the burner so that the proper feed may be secured. We have burners using only 40lbs. per hour, others over 900lbs. (4) For the purposes stated above, metallurgical furnaces, the coal should have a high volatile content, not less than 30 per cent. The coal we are now using analyses: Volatile, 33·20 per cent.; fixed carbon, 56·07 per cent.; moisture, 1·12 per cent.; ash, 9·61 per cent. The sulphur should not exceed 1 per cent.

In the puddling and heating furnaces, the firing grates formerly used for lump coal serve as combustion chambers for pulverised coal, and collect a large portion of the ash. The combustion chamber in the heating furnaces, holding about 6 tons of iron piles, is about 5ft. from back to bridge wall. Some is collected at the base of the stack, and some, in impalpable fineness, passes through the stack. That which falls upon the material in furnace is too small a percentage to unfavourably affect it. In one of our plants, located near a residential section, we have suction fans in the stacks to collect the ash.

Our equipment for preparation of pulverised coal at our

* Paper read before the Engineers' Society of Western Pennsylvania.

Lebanon plant is as follows: The slack coal is conveyed automatically from the car to the pile, then taken by screw conveyors to the dryers, and in the same manner from the dryers to the pulverisers. When ready for use it is similarly conveyed throughout the works, in some cases a third of a mile. It is not touched by hand or shovel from the freight car to the furnace. Using slack coal we do not require a crusher. The dryers are made by several manufacturers. The pulverisers are of two types, the horizontal tube mill and the upright mill. They are practically equal in efficiency, each machine delivering about 4 to 4½ tons per hour. These mills are made by a number of manufacturers.

As the coal leaves the pulverising plant it is weighed on a large automatic scale. The heating and puddling furnaces have each a small automatic scale, and the total of the small scales is checked up each day with the record of the large one. At the end of each line there should be an overflow pipe, to prevent the coal from choking up the screw, if anything should happen to the cross lines. Otherwise, should the coal overflow near an open fire it will burn back very quickly.

Attached to each of our furnaces is a tank or hopper of size to carry about a 15-hour supply of pulverised coal. On several occasions the fuel has ignited in these tanks, usually on Monday mornings when the left over fuel has accumulated moisture. In such cases it is only necessary to stop the supply, and to feed the burning coal into the furnace until tank is empty. There is no danger of explosion under these conditions. Indeed, in our entire experience with this fuel we have had no explosions. These occur from coal in suspension in a room coming in contact with flame. The same result would follow filling a room with wheat flour in suspension. Proper attention to the pulverising plants and machinery will eliminate this possible danger. It is not good practice to have the dryer in the coal pulverising house, for the reason that if an accident should occur causing the coal to overflow, it might be drawn into the fire chamber of the dryer causing fires, with possible injury to employés.

The fuel should be delivered to puddling and heating furnaces at a low air pressure. We use 4 oz. to 6 oz. of blast to blow the coal through a small pipe from the burner to the large blast pipe, which in a heating surface is from 10in. to 14in. diam. This large pipe conveys it to the furnace with a pressure of about 1 oz. or less per square inch. If these pressures are observed the roof and side walls of a furnace heating wrought iron for rolling will last four or five months, when running double turn six days per week.

As to economy of fuel, I show the actual results in our Central Works during the months of April and May, 1913. The figures show the quantity of fuel necessary to produce one ton of puddled bar, made from grey forge pig iron, the product during these months was for high-grade bar requiring special work and time.

	April, pounds	May, pounds
No. 23 furnace	1,362	1,318
No. 24 furnace	1,169	1,277
No. 25 furnace	1,271	1,472
No. 26 furnace	1,371	1,362

The average for same months on a lower grade of pig and cast scrap was 1,239lbs. Our 1912 records show cost of preparing pulverised coal as follows:—

Cost of Preparing One Gross Ton of Coal.

	Cents.
Fuel	0·034
Repairs to buildings	0·002
Operating	0·145
Power (steam and electric)	0·221
Repairs to machinery and equipment	0·200
Total	0·602

This total includes the cost of automatic transmission through pipes to the furnaces. Analysing the last expense item, we find repairs which should be charged over the past eight years, so that total cost of preparation and transmission did not properly exceed 50 cents per ton of pulverised coal produced during 1912. If we separate the transmission from the actual preparation, the cost of the latter would be less than 40 cents per ton. Many plants would not require the extensive transmission required by us. When the coal is prepared as herein outlined, smoke is practically eliminated. If the stacks show black smoke, it would indicate a wasteful use of the fuel to the detriment of the operator's interest, and it is at once corrected.

In heating iron piles for rolling we have the following results during the same months, the figures showing the amount of fuel consumed to produce a gross ton of rolled bar. On steel billets the amount would be one third less.

Name of mill	April pounds	May. pounds
12in. Central	516	528
12in. West	544	570
16in. Central	519	523

HIGH-TENSION OVERHEAD TRANSMISSION LINES.*

BY B. WELBOURN.

In our large industrial centres, where electrical energy is usually conveyed to consumers by underground cables, it is frequently not realised what extensive use of overhead wires is being made in country districts for the same purpose. So far as can be ascertained there are already nearly 1,000 miles of overhead lines in the United Kingdom which are operated at alternating pressures between 2,000 and 20,000 volts inclusive; and of these there are 115 miles in operation or under construction for 20,000-volt working. It is not within the scope of this paper to examine the problem of the distance to which it is commercially economical to transmit electricity in preference to carrying fuel, but it may be recorded that our longest direct transmission line is only about 20 miles in length, while one of 40 miles is under consideration.

It may be taken for granted that pole lines have come to stay in rural districts, where low first cost is of paramount importance in enabling supply authorities to give a cheap supply of energy to industrial works, collieries, houses, &c. It is not necessary to state the case for overhead lines at any length, but it may be well to give the following figures for 3-phase transmission to illustrate the saving in first cost between underground cables and overhead lines. In compiling these figures of costs per mile, care has been taken to include everything required for work of the highest class. Copper has been taken at £60 per ton, and lead at £20 per ton. The copper conductors comprise three of 0·10 sq. in. section in each case. No buildings, transformers, or switchgear are included, and it should be borne in mind that the annual maintenance and depreciation charges on an overhead line are necessarily heavier than on a modern cable system.

Voltage.	Cable Laid and Jointed, including Street Work.	Overhead Line of equal Kilowatt Capacity.
6,000	£1,400	£900
11,000	£1,550	£950
20,000	£2,100	£950

Through this cheapened means of transmission much electrification work is now being undertaken which would otherwise not be commercially possible. The extensive use of overhead lines has thus become of enormous benefit to the manufacturers of electrical plant, cables, and accessories, as well as to the supply authorities and their consumers. The principal difficulty in pole-line work across country is that arising from the necessity of negotiating wayleaves, and these negotiations are frequently very prolonged. The author thinks that a strong case has been made out to justify the Council of this Institution in making representations to the Board of Trade for the benefit of the electrical industry and all consumers with a view to removing the inconsistencies which exist in the law.

All high-tension lines should be designed to comply with the current regulations of the Board of Trade, or with approved modifications, and it cannot be too strongly emphasized that the success or otherwise of all lines will be very largely dependent on the close attention which is paid both to the design and to the erection of every detail. For instance, to secure the best results, it is essential that the en-

* Abstract of paper read before the Institution of Electrical Engineers, January 13th, 1914.

gineers should survey and set out the line and then prepare and issue to the constructional engineers a route plan giving all essential details of what is required.

Considerable criticism was directed some time ago against the requirements of the Board of Trade that the conductors should have a factor of safety of 5 at 22° Fah. and wooden poles a factor of safety at 10, in both cases taking the wind pressure at 30lbs. per square foot of the exposed effective areas, whereas another Government Department — the General Post Office—only used factors of 4 and 8 respectively and took the maximum wind pressure at 17lbs. per square foot. In both cases accumulations of ice or snow are not taken into account. The Board of Trade has made an alteration in its requirements recently by reducing the wind

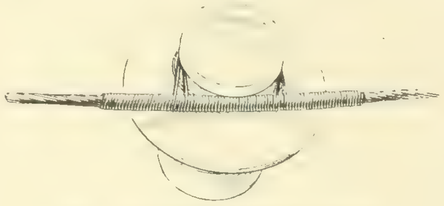


FIG. 1. FLEXIBLE COPPER BINDER.

pressure figure to 25lbs. per square foot, and revised regulations were issued covering this and other modifications in May, 1913. The two cases which are compared are far from being analogous. In the case of the General Post Office the voltage on the wires and the power behind it are not such as are likely to cause any injury to person or animal through shock from a fallen wire; but it is very doubtful whether the General Post Office figures are sufficiently conservative when one considers the extensive wrecking of telegraph and telephone lines which occurs in every snow storm that is accompanied by a gale. High-tension power lines are on a different footing. It is the duty of the Board of Trade to prescribe reasonable precautions for safeguarding the public, &c., from fallen wires, and for the maintenance of a continuous supply of energy to those who are dependent on it.

Wood and Steel Poles.—Most of the work already carried out has been done with winter-felled red fir poles, creosoted by the Bethell process to the General Post Office standard of an average of 10lbs. of creosote per cubic foot of timber. There is good reason to anticipate a life of 35 to 50 years for these poles if they are left undisturbed and if they are erected within a few months after creosoting. The reason for this is that the free creosote drains into the earth around the pole and forms an additional germicide protection. In the last two years much interest has been taken in poles creosoted by the Rueping process, but naturally there is no experience yet of their life on the few lines which have been erected in this country. The poles have some advantages over Bethell poles in that they are both lighter in weight and cleaner to handle. From these points of view and in face of the experience obtained in other countries, poles treated by the Powell saccharine process must also be seriously considered in future.

To obtain the best results it is essential that all poles should be selected, dressed, slotted, bored, &c., at the maker's works before the creosoting is done. The maker should be supplied with detailed drawings showing the finished result required, and the inspection of the poles should take place at his yard whenever possible. When the poles are built up at the maker's works the key-block of A-poles and the brace-blocks of A- and H-poles must be properly marked so as to ensure that they are put together correctly again on the site. Any recess cut in a pole after creosoting should be painted with hot tar. Some engineers have the bottom 9ft. of the pole covered before erection with a preservative mixture consisting of 1½ parts each of Stockholm tar and slaked lime and 7 parts of well-boiled gas tar. Steel structures before delivery should be coated with bitumastic solution; and on that part of the structure which carries the insulators and so normally is inaccessible with safety, the members should also be galvanised before applying the solution.

The choice between steel and wood poles is mainly a question of first cost plus maintenance charges. In the industrial districts of this country there are many reasons why pole lines cannot be run in a straight line, with the result that the spans usually do not exceed 85 yards in length. For such spans it is cheaper in first cost to employ wood poles which require no after-maintenance. Under exceptional conditions longer spans can be used, and steel poles can then undoubtedly be employed with advantage. In the author's opinion steel poles should not be employed in smoke and fume-laden districts without the most careful investigation, because experience with steel poles on tramway and railway systems has shown that the rate of deterioration is rapid and the cost of maintenance in painting, &c., is high. On most lines it is best to deal with angles by using H-poles, which are, when necessary, braced with trussing tackle, and which are equipped with stays and are erected so as to bisect the angle. All channel arms, pins, stay rods, brackets, bolts, &c., should be thoroughly galvanised to the usual standard specification, and where the threads of bolts, &c., are too small to be brushed out while wet in the galvanising process they should be separately sheradised. All stay wires should conform with the Engineering Standard Committee's Specification No. 16 for galvanised wire for mechanical purposes. Convenient standard sizes to use are 7/8 and 19/8 S.W.G. galvanised steel strands, which should not, in the author's opinion, have a breaking strain exceeding 33 tons per square inch, as otherwise the wires will be too hard to be properly workable when nozzling off. All stay wires should be connected to the general earthing system of a line; but when lines are run in mountainous country where it is difficult to obtain good "earths," it is advisable to insulate the stay wire near the pole by inserting in it an insulator of the tramway globe strain type. The nozzles of all stays should be protected from corrosion by being coated with a high-grade bitumastic paint, and unless the threads of all stay rods are galvanised they should be painted with a mixture of 45 parts tallow, 45 parts coal tar, and 10 parts of mineral pitch, as soon as practicable after installation, to prevent them rusting up and becoming useless.

Line Conductors.—Probably 95 per cent. of the high-tension lines are equipped with copper conductors, chiefly because that metal was first in the field, and while it is very uniform in its characteristics it also has a high scrap value compared with its original cost. Our knowledge of aluminium has, however, made rapid strides in the last three years and it has now become a competitor that can no longer be passed over without serious consideration. For instance, cold rolling, coupled with improved manufacturing processes in the United Kingdom, has increased the breaking strain of aluminium by 10 per cent. over that obtained only three years ago. After having erected and watched the behaviour of about 500,000 yards of aluminium conductors (chiefly on

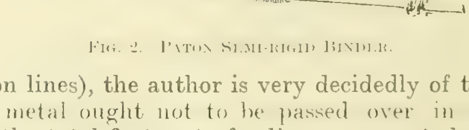


FIG. 2. PATON SEMI-RIGID BINDER.

low-tension lines), the author is very decidedly of the opinion that this metal ought not to be passed over in favour of copper if the total first cost of a line comes out cheaper with aluminium. There are cases where sulphur products abound, *e.g.*, in the neighbourhood of coke ovens, where aluminium should be preferred to copper because it will not be so readily corroded.

There is no standard practice in the case of copper in regard to the use of solid or stranded conductors. On spans up to 50 yards tramway practice may very safely be followed in using solid wires from 11½ S.W.G. up to 4/0 S.W.G. For longer spans and larger sections the conductors should cer-

tainly be stranded because of the additional strength obtainable, and 7, 19, or 31 strand conductors will be suitable. When specifying the breaking strain of the copper, it is very useful to employ a formula of the form suggested by Mr. A. P. Trotter: $T = 30 - 20 D$, where T = breaking strain of each wire in tons per square inch, D diameter of wire in inches. In other respects the copper should comply with the latest British Engineering Standards Specification, dated March, 1910. The "limit of proportionality" on the wire may be taken at 75 per cent., and the minimum size of solid copper conductor now allowed by the Board of Trade on a high tension line is No. 11½ S.W.G.

With aluminium it is essential to use stranded conductors, and there should never be less than seven wires in the strand. The breaking strain of the wires employed in the strand can be obtained from a formula similar to the above, viz., $T = 16{\cdot}5 - 24 D$. In order to obtain suitable wire it is suggested that the specification should call for wire having a "limit of proportionality" of 70 per cent. approximately, and conforming after stranding with the tests set out in the following table:—

Suggested Tests for Hard-drawn Aluminium Conductors.

Standard Wire Gauge.	Diameter of Wire. Inches.	Breaking Strain. Tons per sq. in.	Extension on a 5in. length. Per cent.	Wrapping Test.
4	0·232	11·00	3·00	
6	0·192	12·00	3·00	Three times
8	0·160	13·00	3·00	round its own
10	0·128	13·50	3·00	diameter on
12	0·104	14·00	2·50	and three
14	0·080	14·50	2·50	times off.
16	0·064	14·75	2·50	

The object of the "wrap test" is to ensure that no brittle wire is used, and it should be noted that compliance with the Board of Trade Regulations is only obtainable by ignoring wires larger than No. 6 S.W.G. It is usual to make all joints at insulators and not under strain. There are many ways in which copper conductors can be jointed. The best way known to the author for jointing copper on lines which have to carry heavy loads is by means of copper braids. During calm weather there is no difficulty in making excellent butt-welded joints with blow-lamps on aluminium conductors up to 0·25 sq. in. section, which is the largest section that is likely to be employed in high-tension work.

Spacing of Conductors. Frequently on single poles carrying one 3-phase circuit a triangular spacing of the conductors is obtained by placing one insulator on a ridge iron above the zinc pole roof (with which all poles should be fitted) and two insulators on a horizontal arm below it. While this arrangement economises space, it is not to be recommended, because the pole roof is liable to be damaged and because it is difficult to make the top insulator-support sufficiently rigid in all positions, and particularly on curves. A better arrangement is that obtained by using three galvanised wrought-iron brackets. Two of these can be arranged on one side and one on the other side of the pole, or they can be put all on one side of the pole if there is any possibility of a second circuit being required later. (In passing, it should be noted that no pole roofs of lighter gauge than No. 14 S.W.G. zinc or No. 16 galvanised iron should be used. Anything lighter is of no use in high winds.) In all really heavy work, such as a duplicate-circuit line, steel channel and not wood cross-arms are now generally used, and there is a growing practice to abandon the equilateral triangular arrangement of the wires on 3-phase duplicate circuits, and to erect the wires of each circuit either vertically or horizontally. The latter is the better arrangement when duplicate circuits are needed, as trouble has been experienced with the vertical arrangement through snow loading down an upper wire until it fouled a lower wire. When duplicate circuits are needed it is an excellent plan to place one circuit on a single pole and the second on another single pole at least one pole length away from it if wayleaves can be arranged. The great advantages of this plan are: One circuit can be shut down for repairs, &c., enabling the wiremen to work in safety and quickly, and it is easier to arrange for supply to be given on a ring main system. The second line should be taken by a different route when possible.

It is not possible to give any general rule as to the spacing to be adopted for conductors for any particular voltage, as this varies with (1) the size of conductor, (2) the length of span (3) the windage, (4) the sag, and (5) the horizontal or vertical arrangement of the wires; but it may be taken that the spacing on any length of span should not be less than 3ft. for 20,000 volts., 2ft. 6in. for 11,000 volts, 2ft. for 6,000 volts, and 2ft. for 3,000 volts.

Tying-in of Conductors.—There are three principal methods of tying-in the conductors to the insulators (1) Flexible binders, (2) semi-rigid binders, (3) rigid clamps. In the author's opinion the flexible binder demands the services of skilful wiremen, and is the best both for copper and aluminium if it is made correctly. Fig. 1 shows the copper binder which has stood the test of several years' work on the Newcastle-upon Tyne Electric Supply Company's lines and has never been known to fail. The only semi-rigid binder known to the author is that designed and patented by Mr. G. K. Paton, chief engineer of the North Wales Power and Traction Company, and used successfully by him both on 72½ miles of single circuit employing solid copper conductors varying from No. 4 to 2/0 S.W.G. and on eight miles of single circuit composed of stranded aluminium. The Paton binder was designed to overcome troubles on lines which run over mountains and are subject to very severe weather in winter. Under these conditions it was found that the soft-copper flexible

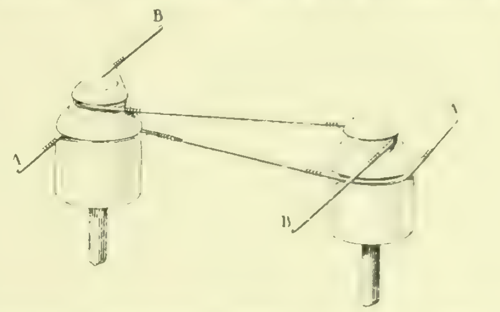


FIG. 3.—SHOWING A METHOD OF TRANSPOSITION OF TELEPHONE WIRE.

binders originally installed stretched and left the line wire loose at the insulator. Vibration in the line wire then caused chafing both of the wire and of the insulator groove, in which the glaze was broken away. Cases were found where the line wire had worn away for 30 per cent. of its diameter, while many insulators failed at the groove. The Paton binder is illustrated in Fig. 2. It is made of solid copper wire, No. 4 to No. 6 S.W.G., according to the size of the line wires of copper. With aluminium lines the aluminium binder varies from No. 2 to No. 6 S.W.G. The binder is formed on a special jig to clip round the neck of the insulator, a standard jig being made for each size of insulator. The binder is hooked on the line wire and then bound under tension at the other end with about 15 turns of No. 14 S.W.G. soft binding wire. A leather or pig-skin chafer is fixed between the line wire and the neck of the insulator, and after five years' use it has been found that the chafer remains as good as new, and does absolutely stop the chafing effects on the wire and the insulator. The whole binder remains tight and is yet flexible owing to the cushioning effect of the chafer. The cost is about the same as that of a well-made flexible copper binder, and about one-fourth the cost of some mechanical clips. It has an advantage over the flexible binder in that no special skill is required for fixing it. There are various forms of rigid clamps in extensive use. When rigid clamps are very carefully fitted by experienced wiremen they appear to give satisfaction, but it is necessary to emphasize the fact that, to get good results, each clamp should be fitted to the insulator on which it is to be used because of the variations in dimensions of all insulators. Some years ago the author investigated two lines on which troubles were experienced, and found that these were due to mechanical clamps. In one case, although well fitted, the line vibration had caused crystallisation and breakage of the metal of the clamps. In the other the clamps had been so badly fitted that they were

moving, with the result that the glaze of the insulators broke and caused the insulators to fail.

Insulators. The pin type of insulator is most in favour in this country, and is likely to continue so while pressures remain at 20,000 volts; indeed, it is quite reliable up to 66,000 volts. The suspension type of insulator is more suitable for really high pressures such as 100,000 volts, and is then the only practicable way of insulating the conductors. We have seen already that the working voltage has scarcely any influence on the first cost of a line, and the author would like to put forward the suggestion that in view of the rapidly increasing loads in industrial districts all main lines should be designed so that they may ultimately be worked at a higher pressure than that at which they are first operated. For instance, 6,000- and 11,000 volt lines might be designed for a pressure of 20,000 volts, and 20,000-volt lines for 40,000 or 50,000 volts. There can be no doubt that the time is approaching when there must be a further raising of working pressures on main alternating current high-tension circuits, similar to the big change which was made in passing from 11,000 to 20,000 volts on underground cables eight years ago. The only commercially possible alternative would appear to be the Thury high-tension continuous-current system.

Whether insulators are made in two parts or not it is of the utmost importance to insist on the parts being put together in such a way that no air cavity can exist. In two-part insulators this can readily be done by putting in the

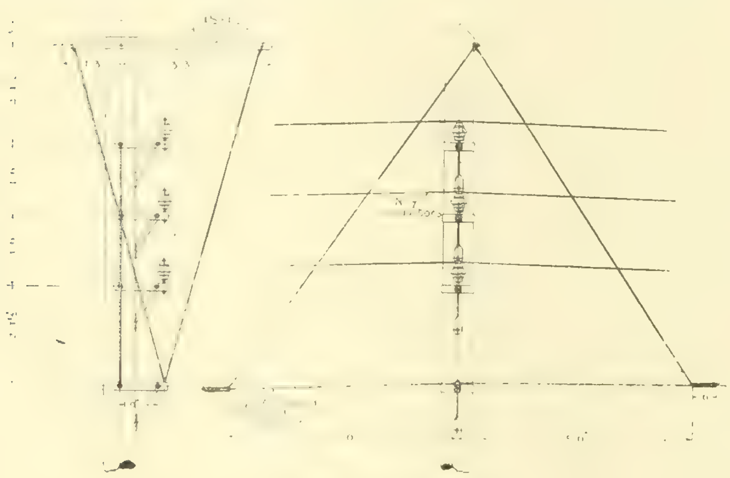


FIG. 1 TRIANGULAR GUARD.

filling cement rather liquid and very slowly. The cement must also be guaranteed to be such that it will not swell or deteriorate on prolonged exposure to damp air. The colour of the insulators is of importance. White insulators have the advantage of more readily disclosing where a breakdown has occurred. On lines comprising two or more circuits it is sometimes advantageous to use insulators of different colour for each circuit in order to prevent mistakes and danger to linesmen. All insulators should be made of the highest grade porcelain which has been vitrified throughout and is absolutely non-absorbent of moisture and free from flaws, cracks or foreign matter. The colouring of insulators is given by the glaze, which must cover the entire surface, except the area where joints are made, and must be free from crazing, bubbles, cracks, &c. On completion, insulators should be tested both electrically and mechanically.

It is important that all insulator pins should be galvanised and should be stiff enough to withstand every normal strain. They may be fastened to the insulator by a cement which will not swell on prolonged exposure to damp air or by packing the free space with hemp or twine soaked in linseed oil in such a way as to ensure that the insulator cannot work loose. Both methods have their advocates. The former is to be preferred where skilled labour is not readily obtainable. The latter method requires considerable skill to ensure satisfactory work, but, when properly done, the author prefers it because of the cushioning effect which is obtained.

Earthing Arrangements. On all the best work a continuous earth-wire, varying in size according to the conditions, is run from end to end of the line either above or below the power wires, and all metal work on the poles, including a lightning spike, is substantially connected to it. The earth-wire itself should be connected to an earth-plate at every fifth pole by means of a conductor (of ample section for carrying the possible leakage current) which is protected from mechanical damage above ground by a creosoted wood strip or other means, and below ground from corrosion by being buried in pitch or being painted with a high-class paint such as P. & B. The connection to the earth-plate must be well made to secure permanent results. One way which the author prefers is to have two bosses cast on the earth-plate with 8in. centres and to drift into these the terminals of a standard copper tramway bond to which is bound and soldered the conductor from above. These connections should be liberally painted as before. The earth-plate itself should be 18in. square and of cast iron not less than ½in. thick, and should be buried in small coke. Experiments have shown that this is the most efficient size of plate to use. Earth-plates may consist of a number of stakes driven into the ground and cross-connected, or of a 9ft. cast-iron pipe buried in coke after cleaning off the Angus Smith solution. The author wishes to lay special stress on the necessity of great care being taken with the installation of the earthing system and its subsequent maintenance, as human life may be dependent on it for safety.

Protection Against Atmospheric Disturbances.—When the continuous earth-wire is run above the power wires it is usually placed there with the intention of also affording some relief from atmospheric disturbances, but not from direct lightning strokes. When placed above the power lines the earth-wire should undoubtedly be of the same metal as the power lines and not of galvanised steel, which has a shorter life than copper or aluminium and will, on breaking, foul the power wires and interrupt the supply. The following are the most important methods which are in use for protection against lightning effects: (1) Air-core choking coils consisting of not less than 12 turns of line wire are installed in series with each line wire to hold back the high-frequency oscillations until a horn-type air-gap arrester placed on the line side of the coil can spark over. In series with the arrester a non-inductive resistance is employed to limit the flow of current to earth to, say, 10 amperes, and for this purpose a carbon-rod resistance may be employed. The author does not place any faith in horn arresters erected in the open air, specially in industrial districts, as the air-gap varies in length due to corrosion and deposits of coal and other dust, and, therefore, requires too much attention. Also it has been shown by various investigators that the pressure in the line cannot be relieved by a spark-gap by more than 20 per cent. if the series resistance is designed correctly to prevent surging at the frequency of the supply. The author is strongly of opinion that any form of arrester which involves a spark-gap is wrong in principle because of the high-frequency oscillatory disturbances caused by a spark in the circuit. Serious damage to plant may be caused by these disturbances unless means are also provided to limit the disturbances to the line itself. (2) Electrolytic aluminium arresters combined with a horn arrester have been used on a small scale, but their extensive use is limited by the fact that they need recharging every day from the line, and this cannot be done without considerable expense from locked-up static substations. (3) Moscicki condensers are coming into favour slowly, possibly because of their high first cost. The condenser arrester is attractive from the fact that it is automatic in action and able to discharge rapidly high-frequency disturbances in the line, while it only needs occasional inspection for the replacement of any blown fuses. It may be well to add that these condensers have not sufficient capacity to afford any improvement in the power factor of a line. (4) After much trouble with horn arresters, Messrs. Merz and McLellan have discarded arresters on all lines which are connected to the system through step-up and step-down transformers, and instead they deal with the problem in a novel way. About 10 per cent. of the end turns on the line side of the transformers are insulated with special materials to a thickness of 300 to 400 per cent. of the insulation on the remaining turns, and what is required is now well understood

by transformer manufacturers. Atmospheric disturbances on the line are reflected back by the end turns of the transformers, and the oscillations are damped out by the ohmic resistance of the line. As the line wires are erected on high-quality insulators it will be seen that only a very high pressure on the line, *e.g.*, a direct lightning stroke, will break down the insulation, and in practice it is found that the outdoor insulators are punctured and the station apparatus is unaffected. The arrangement adopted is effective and cheap and is easily worked in with the general design.

Telephone and Pilot Circuits.—Many lines are provided with private telephone circuits and with circuits for the operation of the well-known Merz-Price protective gear. These circuits may be combined in one paper-insulated cable protected by a lead sheath, to which is added antimony or not less than 2½ per cent. of tin for the purpose of hardening the sheath. Where two or more telephone circuits are required the cable may be of the multiple-twin type arranged to allow of superimposed working. In any case, for mechanical reasons, the insulation on the telephone conductors should be of the dry, solid type, as its capacity, while being higher than that of the air-spaced type is not important on lines up to 40 miles long. The suspension of the sheathed cable is usually done from the steel-stranded continuous earth-wire when it is run below the power wires. In this case the steel strand should be of 40-ton quality, and the sag given to it and the suspended cable should be such that, on completion, the combination runs parallel to the line wires if possible. There have been several failures of plain lead-sheathed cables due to the omission of the tin in the sheath and to improper suspension. The difficulties have been very thoroughly investigated with the result that an entirely satisfactory solution of the difficulty has been found and patented by Mr. C. E. Elder. Briefly, the system consists of very short chrome-leather hangers, which support the cable at every foot, and which are prevented from having longitudinal movement by galvanised wire clips sprung on the suspension strand. On level routes every tenth hanger is also clamped to the cable by a galvanised flat spring clip, but on steep hills every hanger should be clamped.

In suspending lead-covered cables on spans exceeding 50 yards measures should be taken to secure that the cable has no severe bends in the vertical plane. At horizontal bends the cable must be carefully led round the curve by pull-offs on the suspension strand. At terminal poles provision must also be made to carry the cable round an easy bend from the horizontal to the vertical plane in such a way that no movement can take place which would crystallise the lead sheath. The lead sheath should be definitely bonded at every fifth pole to the supporting earth-wire in order to carry away any charges which may be induced in it by the power wires. On lines which are not protected with automatic gear which require a pilot cable for its operation and on which one metallic telephone circuit only is required, it is usual to run two No. 14 S.W.G. phosphor-bronze or hard-drawn copper wires, and of these copper is to be preferred. They may be rotated so as to make one complete revolution at very fifth pole, and in this case it is also advisable to transpose the power wires twice on each route at regular intervals. The rotating arrangement of telephone wires is very unsymmetrical relative to the line wires, but it gives fair results in practice. The author prefers the simpler plan of not transposing the power wires and of not rotating the telephone wires, but of running the latter parallel to one another and transposing them at such regular intervals as may be required. Fig. 3 shows a simple arrangement for effecting the transposition. The author thinks that the cheapness of bare telephone-wire circuits is the only consideration which justifies them. The telephones are most needed at times of breakdown on the overhead line, and then if a power wire is broken the telephone wires may be either "alive" or burnt through if not already broken by a heavier wire falling on them. Failing these, the telephone circuit may be useless through a broken wire coiling round and short-circuiting it, or vice-versâ.

Telephones.—When bare telephone wires are used the only instruments which are permissible are those known as high-tension telephones, which are specially insulated in order to make it impossible for the telephone user to get a shock due to the considerable voltage which is induced on these wires under normal working conditions, or to contact between the telephone and power wires. When paper-insulated lead-sheathed cables are used for the telephone circuits, then the much cheaper low tension telephones of any good make may be employed, but it is advisable to protect them by heat coils, fuses, and spark gaps. It is found that, under fault conditions on the line, the fault current partly travels through the lead sheath and sometimes induces current in the cores of the cables of sufficient magnitude to give severe shocks if the apparatus is not thus protected.

Guarding of Conductors.—With the education of the public as to the safety of overhead wires, the methods of guarding lines crossing railways and roads are becoming much simplified, resulting in reduced cost of construction and enormous gain in appearance. One important 20,000-volt line which crosses a few roads and several miles of mountain moorland much used by tourists, has been equipped throughout with earthed extension pieces of galvanised wrought iron under each insulator. The metal projects for 12in. on each side of the insulator, and the curved portion is nearly semi-circular with a radius of 8in. The triangular guard shown in Fig. 4 is a new arrangement which is due to Mr. A. P. Trotter, and has been used on the Ham line of the Twickenham and Teddington Electric Supply Company and by the Fife Power Company. It has the merits of simplicity, low cost, and ease of erection, and is likely to find considerable favour in future work.

In cases where important G.P.O. lines are met with, the department requires that bare wires working at a pressure of 3,000 volts and above shall not cross its wires, except by special arrangement, thus involving serious expense in extra terminal poles and underground high-tension cables. In some cases the department's requirements have been met by using a joint pole for both sets of wires. For pressures below 3,000 volts the high-tension conductors may be erected above the department's wires by observing certain requirements, of which particulars can be obtained from the Engineer-in-Chief. In the case of parallel telegraph and power lines, the department requires a separating distance not less than one and one-half times the height of the highest power wire or telegraph wire, whichever is greater. With the great attention now given to the details of line construction, and with the equipment of lines with automatic protective apparatus, it is becoming exceedingly doubtful whether any guarding at all is justifiable on such lines. There is reason to believe that the line wires become "dead" within $\frac{1}{80}$ sec. after the occurrence of a fault or short-circuit or the breakage of a wire when the Merz-Hunter split-conductor system is employed. The Merz-Price system will cut out the line with $\frac{1}{20}$ sec. when an earth fault or short-circuit occurs, but it will not deal with the case of the opening of a circuit by a wire breaking until the wire becomes earthed, which may not occur until the wire has reached the ground. Considering these facts, it would seem that the time is approaching when it will be justifiable to ask for the Board of Trade's consent to run high-tension lines along public roads where the conditions are suitable, and so save the enormous amount of trouble that is involved in obtaining numerous private wayleaves.

Cables and Terminal Boxes for Outdoor Use.—Where overhead lines cannot be connected directly to switch gear or transformers by bare conductors, the best practice is to connect up by means of paper-insulated lead-sheathed cables, built when possible to the Engineering Standards Committee's Specification. These cables are usually armoured with galvanised wire for mechanical protection and to form an additional earthed metallic shield round the cable. The armouring should be protected against corrosion, preferably by compounded tapes. Such cables are also used for bridging short gaps in a line. Experience shows that even at 20,000 volts 3-phase there is no need to make provision for protection against lightning where the cable and the line meet, and, further, that cables can be "teed" off an overhead line with safety.

Sundry Details.—(*a*) To prevent the climbing of poles, each separate pole should be equipped with about 10 turns of 4-barbed wire about 8 feet above ground-level, and the wire should be securely stapled to it. In a few cases *chevaux de frise* have been used. (*b*) Each pole should have a zinc number plate (G.P.O. pattern) attached to it by zinc nails at a height of 5ft. above the ground. (*c*) Danger notices must be fixed on at least one pole in five, and on each pole at a road crossing. (*d*) During erection some engineers prefer that wiremen shall use ladders and not climbing irons for going up the pole. This is a wise precaution, but it must be used with discretion. Usually it is sufficient to use ladders at terminal and corner poles. In very hilly country the use of ladders may make the cost of erection altogether disproportionate to the benefit derived. (*e*) Some engineers stipulate that the tops of poles are to be coated with a mixture of coal tar and creosote before the pole roof is fitted. (*f*) Where game guards are required to give warning to flying birds, it is better not to use metal guards, as their swinging has been found to cause cutting of the line wires. It is equally efficient to split and fix on each wire in a span two corks 3in. long and 1¼in. diam. The fixing can be done by binding the two halves of the cork with binding wire. (*g*) During erection and during repair work line wires should always be "earthed." Where this precaution has been neglected, some bad cases of shock to linesmen have been experienced due to electrostatic charges on the wires. (*h*) On completion of erection of a line, it is advisable to subject it to a pressure-test at twice the working pressure for half an hour, or else to make it alive at working pressure for, say, two days before commencing the supply of power.

Standardisation. Transmission line designs have passed through several stages, and it would seem that lines employing wooden poles are approaching finality of design in several districts. In their reliability of operation, good mechanical construction, and general appearance, they will challenge a favourable comparison with any other lines in the world. The author suggests that the Council of this Institution might now usefully consider the appointment of a permanent Transmission Lines Committee with a view to evolving standard specifications of materials, watching and reporting on important modifications of the regulations and practice affecting overhead lines in this and other countries, advising the Council on representations to be made to the Board of Trade, other Government Departments, the Engineering Standards Committee, &c.

Novel Use of Locomotives at a Power Plant.—Being confronted with the problem of replacing an old, inadequate battery of boilers with a new one of greater capacity, Messrs. Schaum and Uhlinger, Inc., of Philadelphia, Pa., according to "The Railway and Engineering Review," took advantage of the fact that the location of their plant, on the main line of the Pennsylvania Railroad, made feasible the storage of locomotives on a long freight siding. Two American type locomotives were obtained and were hauled to a convenient point on the siding. Their throttle valves were closed, and all connections were piped from their auxiliary domes over the fireboxes to the main steam lines in the plant. Although this means of steam supply could hardly be considered economical, it afforded the means of keeping the plant in operation without any interruption during the installation of the new boilers.

Institution of Petroleum Technologists.—The first Council of this Institution has now been appointed as follows: President, Sir Boverton Redwood, Bart., D.Sc.; vice-president, Right Hon. Lord Cowdray of Midhurst; ordinary members of Council, Mr. A. C. Adams, Sir Robert Balfour, Bart., Dr. George T. Beilby, F.R.S., Mr. Edwin R. Blundstone, B.A. (Cantab.), Prof. John Cadman, D.Sc., Mr. John T. Cargill, Major A. Copper-Key, C.B., Mr. E. H. Cunningham Craig, B.A., Mr. Arthur W. Eastlake, M.Inst.M.E., Mr. C. Greenway, Sir Thomas H. Holland, K.C.I.E., F.R.S., Prof. Vivian B. Lewes, F.I.C., Mr. T. C. Palmer, Assoc.M.Inst.C.E., and Mr. Robert Redwood, F.C.S. Sir Frank Crisp, Bart., has been appointed honorary solicitor, and Sir William Plender, honorary treasurer. The applications for membership already exceed 100. Forms of application for membership may be obtained from the secretaries, 17, Gracechurch Street, E.C.

THE STAFFORDSHIRE WROUGHT-IRON INDUSTRY.

AT the opening meeting of the South Staffordshire Iron and Steel Institute, held on Saturday last, Mr. Frank E. Nurse, in his presidential address, stated that during the past 20 years no other industry had participated in such revolutionary practices as the manufacture of iron and steel, more especially the latter. Such ingenious and detailed attention had been expended in probing and understanding the property and intrinsic value of the component parts that manufacture was fast becoming a science, and it was pretty evident that the more scientific the process became the more economical would be its mode of procedure. Much had been done with a view to reducing the cost of production and minimising overlapping charges by grouping together allied interests and intermediary processes, but to such an extent had science entered into present-day works practice that what were but a comparatively short time ago considered mere residuals, looked upon as worthless and often causing vexatious week-end troubles and inconvenience, were now converted into readily marketable products of high commercial value. They were surrounded by tangible evidences of having entered upon a second iron age, but in making the preparatory investigations for his address he felt forced to admit that it would be more accurate to acknowledge the times in which we lived as being a conspicuous part of the scientific age. It was evidence that science was working her harvest for us, and while he was in no way disposed to deprive her of her laurels, so justly due, he felt there was ample vindication for an attempt to designate the present as an epoch of iron. Steel occupied in many departments an invulnerable position by virtue of its adaptability to be manufactured and manipulated in very large masses, and the possession of a congruous quality, which so admirably met the severe and somewhat excessive requirements of the engineer, and they might be quite sure that steel makers would see to it that that position was, at anyrate, maintained.

But there was an increasing sphere for the iron maker, especially now that a revival in the demands of wrought iron had set in. The principal impetus came from some of the largest home railway companies, who, possessing as they did unique opportunities for placing iron and steel under close observation for long periods and in diverse conditions, had conclusively proved that, wherever the size and section would admit of its inclusion, wrought iron was infinitely to be preferred to steel in the construction of the under frames for goods traffic wagons, and, in fact, any part of the rolling stock that might be subjected to corroding influences. The restoration of wrought iron to favour meant much for Staffordshire. No district could be more favourably served by its adjoining coalfields, the close proximity of blastfurnaces producing grades of pig iron so admirably suited for the purpose, and, above all, the lifelong experience of practical men, who had the special advantage of having been reared in the atmosphere of tradition and environment which had made Staffordshire world-famous so long ago. It was to be hoped that local manufacturers would fight tenaciously to popularise the use of wrought iron. They must not forget that good steel was always to be preferred to indifferent iron, and there was nothing that would do so much to quicken the demand for wrought iron as the turning out of a thoroughly reliable and dependable quality.

A matter for mutual congratulation was the prosperous period which employers and employed alike had recently participated in. South Staffordshire, like other districts, had witnessed remarkable fluctuations in the iron, steel, and coal trades, and while, owing to the vicissitudes of industry, it was obviously impossible to maintain anything approaching a state of equilibrium between supply and demand, it was abundantly clear that employment in the iron trade pursuits had a tendency to slacken, and that the inevitable ebb tide was following up the wave of boom trade conditions. Trade had been subjected to the severe strain of a long series of contests with labour, and it was questionable if as much harm had been done by the actual outbursts of hostility as by the depression of confidence influenced by rumours and reports. The past two years had been all too conspicuous for the prevalence

of unrest in the labour world, and incalculable harm had been done to the home and commercial life of this country by the repeated attempts to adjust differences by means of strikes. Available information proved that it was far more beneficial to treat with the employers direct, or with the authorised conciliatory or arbitration boards, and avoid by all available means those excessive hardships which followed when men quitted work in a body.

An exceptional hardship peculiar to Staffordshire, isolated as it was in the centre of England, which was more acutely realised in times of severe competition, was the disadvantage it was placed in through the lack of enterprise in our canal system, which remained unaltered from the time of its conception, and, since its controlling interests had been purchased with railway capital, competition with railway rates to the seaboard was eliminated. It was encouraging to note that a Royal Commission were so favourably impressed by the evidence put before them that they had recommended that definite action should be taken so far as the English canals were concerned, and it was to be hoped that the increasing and influential opinion favourable to the scheme would ensure an early movement in this direction. It was surprising, however, what comparatively little interest was taken in matters of such vital and national importance to England's trade development by State and municipal authorities.

In conclusion, he appealed for a more active interest in matters which closely concerned everybody's welfare. The iron and steel maker should take a more practical interest in the agriculturist's problems, which hampered him as a producer. The encouragement of home production created the best of customers, and considerably enhanced our general prosperity. He could not speak too highly of the work carried on by the institute. He often felt, however, that it did not receive that warm and generous support of employers, either large or small, which it deserved, but he hoped it would increase in popularity and usefulness.

INDUSTRIAL AND TRADE NOTES.

High-speed Steel Competition.—The Belgian War Office is organising a high-speed tool steel competition, full particulars relating to which can be obtained from the Fonderiè de Canons, 80, Quai Saint Leonard, Liége. Entries must be sent in not later than February 15th.

German Machine Industry in 1912.—A report in the "Frankfurter Zeitung" gives the results of the machinery industry in Germany in 1912. The report covers the working of 260 companies (out of the 312 companies in the industry), with a total nominal capital of 679 million marks. Of this capital, 62 millions were paying no dividend, 93 millions were paying up to 5 per cent., 342 millions between 5 and 11 per cent., 101 millions between 11 and 16 per cent., 52 millions between 16 and 21 per cent., 6 millions between 21 and 25 per cent., and 23 millions over 25 per cent. The figures for last year show an improvement over the preceding two or three years, which improvement can be seen by the increased number of companies paying a dividend, and by the increase in the reserve funds of the various companies.

Amalgamated Society of Engineers and the Termination of the Agreement.—The January report of the Amalgamated Society of Engineers contains the text of a letter sent to the Engineering Employers' Federation giving three months' notice as from December 8th last to end the terms of agreement, 1907, also the premium bonus system. In the communication it is explained that the recent delegate meeting, whose functions are to amend and make rules, laid it down that the Executive Council must take the votes of the members for or against the continuance of both bargains. These votes were taken, and an overwhelming majority of votes was cast for ending them. "In consonance with these votes," the letter continues, "we hereby give three months' notice" to terminate the agreements.

Lloyd's Shipbuilding Returns.—The shipbuilding returns for 1913 compiled by Lloyd's Register show that, excluding warships, there were 513 vessels of 1,956,606 tons gross under construction in the United Kingdom at the close of the quarter ended December 31st, 1913. The vessels include 490 steamers of an aggregate gross tonnage of 1,952,814 tons and 23 sailing ships aggregating 3,792 tons gross, making a total of 513 vessels of 1,956,606 tons gross. Compared with the tonnage under construction at the end of December, 1912, these figures represent a decrease of 13,459 tons. They further show a decrease of 30,648 tons under the figures at the end of September, 1913. Of the 513 vessels under construction 12 are between 10,000 tons and 12,000 tons, 11 between 12,000 tons and 15,000 tons, 9 between 15,000 tons and 20,000 tons, 4 between 20,000 tons and 30,000 tons, 1 between 30,000 tons and 40,000 tons, and 2 over 40,000 tons. There are 82 British warships under construction, 16 of 162,460 tons displacement at the Royal dockyards, and 66 of 319,171 tons in private yards. Eleven warships of 123,170 tons are being built for foreign Governments.

Patents and Trade-marks.—Mr. A. J. London, president of the Dunedin Chamber of Manufactures, in his evidence before the Dominions Royal Commission taken in New Zealand last year, said that body desired that consideration should be given to the question of patent laws and trade-marks, in the direction of their simplification, and also to the feasibility of establishing a national patents trade-marks office, governing all the patent rights and trade-marks applied for or granted within the empire. It could hardly be disputed uniformity would be a great benefit. The suggested patents and trade-marks office should be the head filing office for the Empire, all applications for letters patent being made to it, and examined and granted or refused by it. To conserve the revenues from patent fees, at present accruing to the individual States, the empire could be divided into States or sections, and a sliding scale of fees prescribed. Sub-offices would be established in each State for deposit purposes only. Instead of having 20 or 30 different patents to keep in force in all the 30 or so States, the patentee would have to look after only the one patent registered in the office in London. The registration of trade-marks within the empire would be carried on in a similar way to the grant of patents, by a central office in London and sub-offices in each State.

Proposed Russian Hydro-electric Scheme.—H.M. Consul at Helsingfors reports that it is stated in the local press that the committee appointed by the Senate to investigate the water power of Vuoksen formulated a scheme under which 90,000 h.p. could be obtained from the Imatra Falls, at a cost of about £880,000. Before the committee could issue a memorandum on the subject, however, a Franco-Russian company applied to the Finnish Senate for permission to survey the territory along a line drawn from any part of Lake Saima to the Kuurmanjoki river, with a view to constructing a channel along this line, and concentrating all the rapids in the Upper Vuoksen into one place. The Senate directed the above-mentioned committee to carry out the requisite survey. The result is not known, but it is reported that the channel would be 18-20 kilometres in length, and take a course almost straight down from the village of Karsturanta, at Lake Saima, to the village of Kuurmanpohja, where it would join the river Kuurma. The principal power station would be built at Kuurmanpohja, where the channel makes a fall of nearly 200ft. The waterfall at Kuurmanpohja would afford 300,000 h.p., and would to a very great extent provide electric power for St. Petersburg, Viborg, and the Finnish State Railways. It is estimated that the power station and the channel will cost about £4,000,000. It is not known whether the Government has decided to carry out its own project, or if it will hand over the whole property to the Franco-Russian company.

Electricity Supply Statistics for Germany.—Some interesting figures relating to the electricity supply business in Germany are given in last week's issue of "The Electrical Review." The figures have been collected by the Verband Deutscher Elektrotechniker, and published in alternate years, those for the two years ended with April 1st, 1913, having just been issued by the firm of Julius Springer, of Berlin. The information does not apply to power stations which solely serve the purpose of furnishing electrical energy for the operation of railways and tramways, or to stations which supply to blocks of buildings or to individual installations (factory or ironworks' stations), unless they also deliver energy for sale to the public. With these reservations, the statistics deal with all the stations throughout the country which are concerned with meeting the public requirements in regard to lighting, cooking and heating, and power purposes. The increase in the number of public stations in recent years has been surprisingly large, although many of them are of comparatively small capacity. For instance, on April 1st, 1911, the number had advanced to 2,526, and on April 1st, 1913, it had further risen to 4,040, so that the stations have more than doubled in a period of four years. The figures also represent an average of nearly 15 new stations per week in the past two years, or about two new works opened daily. The capacity of all works combined in 1911 and 1913 was 1,466,418 kw. and 2,095,666 kw. and the average capacity per station 580 kw. and 519 kw. respectively. The reduction in the average capacity of the stations, which had always increased in former years, is attributed to the large expansion in the number of new stations, which nearly always commence on a small scale. Works capable of dealing with 5,000 kw. and over numbered 53 in 1911, of a total of 816,746 kw., and in 1913 to 103, of a total of 1,560,752 kw. The principal position is occupied by

the Berlin Electricity Works with a capacity of 193,000 kw., the second place is held by the Dusseldorf Reisholz Works with 65,000 kw., and the third by the Upper Silesian Electricity Works at Gleiwitz. The capacity of the connections, as represented by lamps, motors, &c., amounted to 2,465,976 kw. in 1911, of which 38 per cent. were for lighting and 62 per cent. for power, and 3,725,769 kw. in 1913, 36 per cent. being for lighting and 64 per cent. for power. The number of localities where public supply is in operation was 11,000 in round figures in 1911, and 17,500 in 1913. Allowing a sum of £60 as the average capital invested per kilowatt capacity of the station, and as the total capacity of all stations was 2,100,000 kw. on April 1st, 1913, the total capital investment works out on this basis at £126,000,000, excluding the installations on consumers' premises.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1912.

Method for obtaining the charge unmixed with combustion products in internal combustion engines. Kylliainen. 21759.
Power operated portable hammers. Electric Hammers, Ltd., and Scott. 24090.
Process for rendering non ductile metals ductile. Trenzen. 26800.
Apparatus for governing, controlling, reversing, and stopping internal combustion engines. Hammersley, and W. H. Dorman & Co. 26941.
Two stroke cycle explosion motors. Colmant. 29258.
Oil gas producers. Bates. 29275.
Vaporisers and explosion chambers of internal-combustion engines. Crossley & Webb. 29337.
Steam-heating systems for railway trains. Pintsch's Patent Lighting Company, and Sawyer. 29487.
Lubricating apparatus for internal-combustion engines. Newey and Newey. 29519.
Forcing water into boilers. Gordon. 29618.
Actuating the valves of internal combustion engines. Jackson. 29659.
Brakes for railway vehicles. Ayers. 29688.
Air brake mechanism. Farrell, and Chas. Macintosh & Co. 29767.
Internal combustion engines. Sands & Sands. 29806.
Thrust bearings. Parsons. 29810.
Internal combustion engines. Vanderlip. 30081.

1913.

Cleaning metallic surfaces. Thompson. 9.
Calliper gauges. Bell. 198.
Valves and valve arrangements for internal combustion engines. James. 341.
Steel roller chain. Campbell. 441.
Fuel admission valves for internal combustion engines. Carter. 499.
Winding and haulage drums. Davenport. 1355.
Distilling feed-water for boilers. Soc. d'Exploitation de Procèdes Evaporatoires Système Prache et Bouillon. 1583.
Clutches. Lianosoff. 2293.
Power-transmission for self-propelled vehicles. Horsley, and Daimler Company. 2478.
Thermal treatment of steel ingots and castings. Marks. 2484.
Pipe couplings. Escreet. 2678.
Pumps. Franklin. 3542.
Hydraulic power transformers. Heindl. 3692.
Two-speed chain safety lifting blocks. Sturrock & Baggesen. 3726.
Flexible couplings. Homersham & Berk. 4080.
Hammers actuated by air or fluid. Lang. 5493.
Shaft couplings. Withers. 6195.
Vices. Swinden & Swinden & Co. 7065.
Hydro-carbon engines. Roberts. 8400.
Valve mechanism for internal combustion engines. Reinhard. 8604.
Engine lubricators. McKenna. 8683.
Apparatus for transmission of power. Hautier. 8846.
Wrenches. Huber. 9279.
Facing tool for boiler manholes. Curran. 10241.
Check-feed valve for marine boilers. Green. 10511.
Driving-mechanism for automobiles. Fleury & Morin. 13190.
Instruments for making calculations in regard to toothed gearing and other problems. Young. 16237.
Adjustable reamers. Fox. 16882.
Steam or gas turbines. Vulcan Werke Hamburg und Stettin Akt.-Ges. 17019.
Preventing and removing incrustations from steam-boilers. Oliveras. 17288.
Combined pressure reducing valve and throttle valve. Bousfield. 18730.
Piston-rings or packing for explosion engines. Descourtis. 19707.
Flap valves for pumps and compressors. Akt. Ges. Brown, Boveri, et Cie. 20641.
Turbines. Jones & Patchel. 21839.
Safety valves for steam boilers. David Auld & Sons, Ltd., Auld, and Graham. 22195.

ELECTRICAL, 1912.

Wireless telegraph systems Shephard & McKechnie. 21743.
Regulation of rotary converters. British Thomson-Houston Company, and Whitaker. 26899.
Method of reproducing electric variations. Arnold. 29384.
Electric accumulators. Heap, and Chloride Electrical Storage Company. 29456.
Means and method of operating liquid electric controllers and starters. Baerlocher & Allen West & Co. 29461.
Dynamos. Soc. Système de Traction Auto-Regulateur. 29522.
Electric igniters. May. 29613.
Electric ignition generators. Lawrence. 29620.
Impulse-sending mechanisms. Western Electric Company. 29719.
Electric cooking and heating appliances. Railing & Garrard. 29763.
Electric couplings. Lucas & Edwards. 29809.
Detachable electric immersion heater. Ide. 29879.

1913.

Substitution resistances for electric lamps. Heins. 9530 and 10018.
Amortisseur windings for synchronous dynamos. British Thomson-Houston Company, and Whitaker. 9685.
Electric switches. Fagerlund. 13654.
Electric lighting indicator. Hutton. 13660.
Geared alternating current electric motors. Siemens-Schuckertwerke Ges. 24126.

METAL QUOTATIONS.

TUESDAY, JANUARY 13TH.

Aluminium ingot	90/- per cwt.
,, wire, according to sizes, &c. ......from	117/- ,,
,, sheets ,, ,, ... ,,	112/- ,,
Antimony £28/-/-	to £30/-/- per ton.
Brass, rolled	7½d. per lb.
,, tubes (brazed)	9⅝d. ,,
,, ,, (solid drawn)	8⅜d. ,,
,, ,, wire	7⅝d. ,,
Copper, Standard	£62/17/6 per ton.
Iron, Cleveland	50/6 ,,
,, Scotch	56/6 ,,
Lead, English	£19/15/- ,,
,, Foreign (soft)	£19/12/6 ,,
Mica (in original cases), small	6d. to 3/- per lb.
,, ,, ,, medium	3/6 to 6/- ,,
,, ,, ,, large	7/6 to 11/- ,,
Quicksilver	£7/10/- per bottle.
Silver	26⅝d. per oz.
Spelter	£21/11/3 per ton.
Tin, block	£168/-/- ,,
Tin plates	12/9 ,,
Zinc sheets (Silesian)	£25/-/- ,,
,, (Stettin; Vieille Montagne)	£25/2/6 ,,

The Production of Small Castings.—A lecture on "The Comparative Metallurgical Considerations involved in the Production of Small Castings" was delivered by Mr. W. H. Hatfield, D.Met., of Sheffield, at a recent meeting of the Coventry Engineering Society. Mr. Hatfield dealt with the commercial alloys of iron and carbon, and generally discussed the whole range of the iron and iron-carbide equilibrium diagram. After illustrating the micro-structure of various pig irons, he discussed the influence of varying micro-structure upon the physical and mechanical properties of iron castings in both the cast and annealed conditions. He then proceeded to discuss malleable castings, and by a series of slides indicated the influence of variation in composition both upon the method of production and final product. The lecturer also discussed the metallurgical problem of producing small steel castings which is now receiving attention.

The Mechanical Engineer.
An Illustrated Weekly Journal
Vol. 33, No. 835.

Edited by
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Telegrams: "Scientific," Manchester.
Telephone No. 6055 City.

SUBSCRIPTION RATES.

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The Development of Steamships.

THE relative influence exerted by various factors, such as size, speed, cost of construction, harbour facilities, and alternative routes such as the Suez and Panama Canals, on the development of steamships have often been separately discussed, but their collective effect has not hitherto been presented as it has been in a memorandum prepared by Prof. Sir John Biles and Lord Pirrie which has been issued by the Dominions Royal Commission. The subject is one of supreme engineering, as well as commercial, interest, and the eminence of Prof. Biles as an authority on all matters relating to ship construction gives special importance to his replies to the various questions submitted to him. Referring to the question of size and the extent to which the assumption is valid that a given volume of cargo and passenger traffic can be carried more economically in a few large steamers than in a large number of small steamers, a great deal depends on circumstances, and especially the relative proportions of passengers and cargo; but, as a general proposition, it may be said that if unrestricted draught is available the large vessel will carry her load more economically than the small vessel. The consideration of cargo freight and passenger revenue is obviously complicated and not amenable to a precise rule. Prof. Biles states that where cargo is carried in passenger ships over 750ft. in length the cost steadily increases until, at 1,000ft., it becomes 40 per cent. more, and also that the ideal economic dimensions for a mixed cargo and passenger ship would be those coming within the working draught of the harbour. For instance, if this were 40ft., the dimensions for a 14-knots speed would be about 700ft. in length by 87ft. in breadth and 71·4ft. in depth. If the dimensions of this ship were increased without increase of draught, the cost per ton rapidly increases. So far investigations have only been carried out at two speeds—12 and 14 knots. The 12-knot vessel has a most economical length of about 750ft. In the 14-knot vessel the economic length is 700ft. if there is no revenue

from passengers, but if she carries her full complement of passengers the 1,000ft. ship would be about as economical as the 750ft. vessel. In other words, in the 14-knot ship the economic length may be as low as 750ft. and cannot be more than 1,000ft. At 17 knots the economic length for cargo carrying, when there is no passenger revenue, is 800ft., but with a full complement of passengers the 1,000ft. ship might be as good, and thus the most economical length must lie between these limits. Speaking generally, it may be said that as speeds increase the economic limit increases also, and for a 20-knot speed it would appear that the vessel should be at least 1,000ft. in length, with a draught of 57·6ft.

Associated with the question of size is that of speed. Assuming, for example, a given speed, in what ratio does increased size provide lower cost of transport, or alternatively, assuming vessels of a given size, in what ratio does increased speed affect cost of transport? Discussing the first and alluding to the obvious fact that there is a certain limit to reduction of transport cost consequent upon increased size, and further, that the reduction of cost tends to fall off at the greatest lengths, he expresses the opinion that on account of the ratio of hull weight to total displacement tending to increase as size increases there is some length at which a minimum cost will be found, though this length has not yet been reached. To determine this length at any approach to accuracy is a complex question and involves the whole subject of ship construction, since the scantlings and weights are based upon certain assumptions as to the wave length the ship is likely to meet, and which, though justifiable within the limits of present practice, would not come into consideration after a certain size of ship was reached. This conclusion is based on the fact that wave lengths will not increase or affect the stresses in the ship, regarded as a beam supported on wave crests to the extent they do in ships at the present time. The answer to the second question is different for different sizes of ships. For a length of 600ft. the cost per ton-mile at 17 knots is 63 per cent. more than at 14 knots, and at 20 knots is practically prohibitive. For a length of 700ft. the cost at 17 knots is 32 per cent. more than at 14 knots, and for lengths of 900ft. to 1,000ft. about 18 per cent. more. Similar differences are observable for increases of speed from 17 to 20 knots. For a length of 700ft. the cost at 20 knots is more than double that at 17. For 800ft. the increase of cost is about 50 per cent., for 900ft. 30 per cent., and for 1,000ft. 17 per cent.

The influence which the Suez and Panama Canals are likely to exert on ship development is not easy to estimate, especially as regards the latter, on account of the variable factors which will come into play and the difficulty of determining their magnitude in advance. A consideration, however, of figures given in Sir John's report would seem to show that the tendency is undoubtedly towards increase in size. The percentage of the total formed by vessels between 2,000 and 3,000 tons is steadily decreasing; between 3,000 and 4,000 tons the percentage increased from 1903 to 1907, when it reached a maximum and has since steadily declined; over 4,000 tons the percentage has steadily increased over the whole period shown in the table, and for vessels between 5,000 and 7,000 tons the increase is more rapid. For ships over 10,000 tons the increase in 1910-11 was 2 per cent., and for 1913-14, 2·7 per cent. In 1912-13 there were 17 ships between 15,000 and 20,000 tons, while in 1913-14 there were 29 ships between these limits, and in no case has there been a decrease in numbers in ships over 10,000 tons, the total increase in such vessels for the last year being from 177 to 206. That insufficient depth of harbours is exercising a restricting effect is shown by the fact that the modern large vessel has not the most economic ratio of draught to breadth and length which freedom of design would accord, and until the defect of distant ports is remedied little advantage will be gained by the practicable deepening of the Suez Canal. It may be that the draught of 40ft. which will be available in the Panama Canal will exercise an influence on certain routes to China by permitting the use of economic steamers of greater length, although the distance would be greater. But in this, as in comparisons with the Suez Canal and the Cape route, many things have to be considered. The time by the canal is less, and with it the coal bill. On the other hand, coal can be obtained more cheaply on the Cape route, and hence the gain in one direction may be easily balanced by loss in another. Seeing that for most economic transport a vessel of at least 750ft. in length, with a draught of 43·2ft., is required, a draught of at least 45ft. of harbour should be provided, and having regard to the further economies which would probably result from the use of ships 1,000ft. in length, with a draught of 57·6ft., Sir John ventures to predict that within 20 or 30 years a harbour depth of 60ft. could be profitably employed. Such terminal requirements must obviously exert an economical pressure on the Suez and Panama routes, for there are alternatives to both. This pressure has led to continuous deepening of the former, though if this were continued at the present rate it would take many years before the depth reached 40ft. If, therefore, Sir John's prediction is fulfilled at the Antipodes, the deepening of the Suez Canal will require to be accelerated or much of the traffic transferred to the ocean route. Lord Pirrie's contribution to the memoranda consists of answers to questions respecting the maximum draughts of ships and harbour provision, and are in the main confirmatory of those arrived at by Sir John Biles. In considering them it should, of course, be borne in mind that the memorandum under notice is concerned more particularly with the main trade routes between this country and the overseas dominions, and though the vessels of the maximum size advocated have already been built, their success is to some extent the product of traffic conditions on the Atlantic route, where the flow of passengers and goods is large, and high rates are willingly paid for rapidity and luxury of transport. These factors do not exist to the same extent on other routes, and though economy results from increase in size, and the figures of the past show the tendency to be in an upward direction, the curve may reach a summit before the dimensions indicated are attained.

Recovering Oil and Waste.—According to the "Electric Railway Journal," the Denver City Tramway Company cleans the oil and waste used in the car journals in a tank 5ft. 6in. long, 3ft. 6in. wide, and 17in. high, in which is a horizontal screen on which the picked waste rests. Clean, hot oil is poured over the waste, and after this oil has dripped away the waste can be used again The oil used for washing is filtered and used again. About 150lbs. of journal and armature waste are worked through the tank every week. No new waste has been purchased since December, 1912, when the plant was first used. All car motors are oiled every ten days.

SUPERHEATERS FOR SURFACE-COMBUSTION BOILERS.

THE accompanying illustrations show diagrammatically two arrangements for superheating the steam in boilers of the surface-combustion type which have recently been patented by Bonecourt Surface Combustion, Ltd., Parliament Mansions, Victoria Street, Westminster, S.W. In Fig. 1 only one tube and part of the steam generator is shown. The arrangement comprises a pair of concentrically disposed pipes A B. The outer pipe A is closed at its inner end, *i.e.*, the end adjacent the refractory material, by a cap C of such thickness that burning out will not quickly occur. The outer end of the pipe A is connected with one compartment D of a steam header. The pipe A passes through the inner wall E of the header, and its outer or free end is secured in a hole formed in a second or central wall F of the header. The outer or free end of the pipe, and therefore the hole, is closed by a plug stopper G, the plug being provided with a central orifice through which the inner pipe passes. The inner pipe B extends within the pipe A for nearly the full length, and its outer or free end is in connection with a second compartment H of the steam header. The compartments D H are not in communication the one with the other except through the pipes A B, and are in communication the one, D, with the steam space of, or the steam supply pipe from, the steam

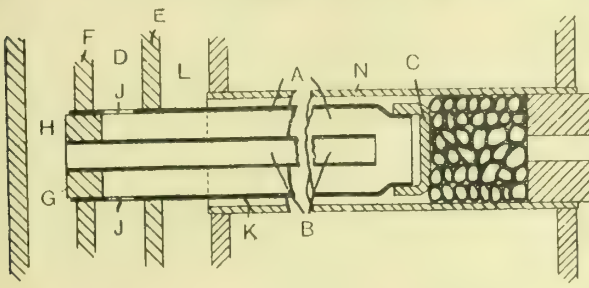


FIG. 1.

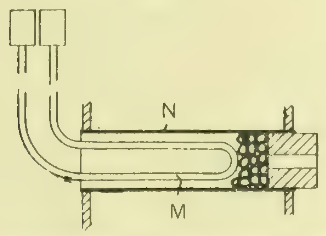


FIG. 2. ARRANGEMENTS OF SUPERHEATERS FOR SURFACE COMBUSTION BOILERS.

generator, and the other, H, with the pipe supplying the engine. The pipe A is in communication with the compartment D through openings J formed in its walls. Steam passes from the steam generator to the compartment D and from this compartment through the openings J to within the pipe A; the steam flows along the pipe A to its inner end and enters the inner end of the pipe B, along which pipe it passes to the compartment H, and so to the engine. The external diameter of the pipe A is such that a space is formed by and between its outer wall and the inner wall of the tube N, and this space forms a passage K for the flow of hot products of combustion. The passage K, and the space between the pipes A B, may be packed with refractory material. The products of combustion that escape from the passage K enter the space L and thence pass to the flue or uptake. In the construction, shown in Fig. 2, a U-shaped pipe M is contained within a tube N and its ends are connected with the steam supply and take-off means. Here it will be seen that the superheating is done near the U bend and that if the superheating tubes are embedded in refractory material the heat remaining in the products after superheating is effected is transmitted through the latter part of the tube N to the water in the boiler.

The Society of Engineers.—An ordinary meeting of this society will be held on Monday, February 2nd, at the Institution of Electrical Engineers, Victoria Embankment, W.C., when Mr. Arthur Valon, M.Inst.C.E. (president 1913), will present the premiums awarded for papers published in the "Journal" during 1913, and Mr. H. C. H. Shenton, the president for 1914, will deliver his presidential address.

COMMERCIAL TESTS OF INTERNAL-COMBUSTION ENGINES.*

BY W. A. TOOKEY.

THE circumstances under which gas and oil engines are operated, when installed in factories, usually preclude an engineer from carrying out any desired tests upon the exact lines which have been suggested by committees of engineering institutions in England, Germany, and America, and which have been formulated with the object of effecting a standardisation of results by means of which proper comparison can be made. In the laboratories of technical colleges tests can be conducted according to schedule, and on makers' test beds—very occasionally—records of desirable observations are sometimes heard of as being more or less complete in connection with engines of novel characteristics. But the conditions applying in the case of industrial works in which gas or oil engines have been installed for driving the machinery are usually not such as will allow the application of any form of dynamometer. No direct measurements can be taken of the quantity of heat absorbed by the cooling water or rejected in the exhaust. No direct measurement of the air admitted into the cylinder is practicable. In fact, it is rarely possible to do more than to measure the gas consumed or to weigh the liquid fuel, and to indicate the engine with due care. From these two operations all information must necessarily be obtained.

During the past few years the author has been called upon to make tests of over 700 gas engines, of various sizes and types, working with town gas, within the London area, and the present paper describes the method adopted by him to enable reliable comparisons to be made respecting the performances of these widely differing engines. An extensive series of tests was undertaken on behalf of the Gas Light and Coke Company, and also, and in greater numbers, for the South Metropolitan Gas Company. The objects in view were to note the performances of the engines in their condition "as found," to improve such performances when it was possible to do so by adjustments of mechanical details, and to report whether still further improvements could be expected, if proper attention were paid to necessary repairs or renewals of worn parts. The two London gas companies concerned realised the fact that many of the thousands of engines used by their consumers were expected to work year in and year out with the very minimum of attention beyond starting, stopping, and lubricating, and therefore it was to their interests, although indirectly, to ensure that the utmost work could be obtained from the least volume of gas. The whole cost of the survey was borne by them, and that the consumers have benefited very considerably will be evident from the following statement:—

Up to October, 1913, the number of engines inspected and reported upon was 763. A considerable proportion were found to be well looked after and maintained in such good order that very little improvement was possible. On the other hand, some had been so neglected that no improvement could be effected without previous overhauling, more or less extensive. Quite a number of old type, slide valve engines are still doing good work with such moderate gas consumption that, for the amount of horse-power hours developed, the savings in the cost of gas obtainable by utilising modern gas engines, despite the greater efficiency of the latter, would be insufficient to recoup the interest on capital outlay involved in their replacement. Examples of gas engines have been met with, the mechanical details of which necessitated reference to early editions of standard gas-engine books, especially in the case of two-cycle engines with displacer cylinders, six-cycle double-acting engines, and others working upon the four-stroke cycle, but with complicated valve gear that demanded some little study before one could appreciate their peculiarities.

It was found to be possible to improve the working of 66 per cent. of all the engines tested, merely by adjustment to gas or air regulation or by correction of ignition timing and valve-setting. A greater proportion could have been improved had new parts been fitted and had attention been given to matters which would involve stoppage for periods varying from a few hours to a few days. In all cases where renewals or overhauling appeared to be imperative, recom-

* Paper read before the Institution of Mechanical Engineers, [illegible] 1914.

mendations were made to the user to call in the makers or a firm of expert gas-engine repairers to put matters right. In some instances such improvements as could be made at the time increased the power developed per impulse, as well as reduced the consumption of gas; in others either the output or the efficiency, but not both, was increased. The average improvement as regards increase of power per impulse was 27 per cent. For example, an engine found to be giving a mean pressure of, say, 60lbs. per square inch would be left giving 76lbs. with the same, or even decreased, gas consumption, under the same load and speed. The average reduction in gas consumption was 13·3 per cent. on the indicated horse-power hour basis.

It was essential that all tests should be conducted in such a manner that no stoppage of the work of the factory in which the engine was fixed was involved, and further, that the adjustments made should be such as would bring about improvements in working, not so much under "light" or "maximum" loads, but that which accorded with the average output in daily work. Following upon a preliminary inspection, at which was noted the size, type, and make of engine, arrangements were made to fit up the indicating gear and to check over the valve-settings—which gave opportunities for close examination of all mechanical details—during the mid-day meal hour. As may be imagined, sometimes considerable difficulty was experienced in noting all the necessary observations, as well as in fitting up the reducing gear, within the space of one hour. While the indicator gear was being fixed and the valve-settings were being checked, the opportunity was taken of noting whether the gas-meter index remained stationary while the gas-bag was kept fully distended and with the ignition-tube burner turned "off." Any variation noted in the interval gave the rate of leakage, if any, in the supply pipes.

After the indicator gear had been properly fitted and the valve-settings taken, the engine was started up, and very shortly after, as soon as a trial card had been taken and examined, other diagrams were obtained and, at the same time, the impulses per minute and number of revolutions per minute were counted, and the gas consumption per minute was noted while the engine was running without any load except that due to the main driving belt running on the loose pulley. This trial was known as "light, as found." The shop load having been put on, a similar series of observations were taken and noted as "load, as found." The diagrams referring to the latter were then worked out on the spot and calculations were made, as explained later, to note the mean pressure obtained with respect to the mixture strength.

From the previous checking of the valve-settings and the information afforded by the "load, as found" cards, together with an examination of the curves recorded upon a diagram taken with a light spring, it was then possible to decide which, if any, adjustments should be made to bring about improved performances. Several diagrams were thereupon taken under different conditions, until it was determined, by means of temporary adjustments, exactly how to achieve the desired results. Occasionally the improvement could be effected within a short space of time, but frequently several hours were spent, according to the condition of the engine, before a satisfactory result could be obtained.

TABLE I.

TEST No. 595A. Date: Feb. 13th, 1913.

Name: S. & Co. 2 Meters: 300 lt. No. 906089.

Address: Bermondsey, S.E. 300 lt. No. 37388.

Assistant's Initials: A. R. P.

Machinery driven: Dynamo and cocoa-grinding plant.

24″ × 30″ (———) Gas Engine No. 10841.

R.p.m. { Light: 155.
Load: 154.

Specific piston displacement $\left(\frac{A. \times S.}{1728}\right)$ = 7·854 cub. ft. per stroke.

Governor: Hit-and-miss.

I.h.p. constant $\left(\frac{A. \times S.}{396,000}\right)$ 0·03427.

Ignition: Two magnetos (low tension).

Piston positions from edge of liner - in centre: 23·375″ in; out-centre: 6·625″ out 30″ stroke.

Exhaust valve setting	Open;	piston 1″	out;	crank ♂	: lead 5·625″.
	Close;	,, 14·5″	in;	,, ♉	: lag 8·875″.
Mixture ,, ,,	Open;	,, 22·75″	in;	,, ♀	: lead 0·625.″
	Close;	,, 3·875″	out;	,, ☌	: lag 2·75″.
Gas ,, ,,	Open;	,, 20·5″	in;	,, ♉	: lag 2·875″.
	Close;	,, 6·25″	out;	,, ♂	: early 0·375″.

Compression pressure: 120lbs.

Compression pressure ratio $\left(\frac{C.P. + 15}{15}\right)$ =9·0.

Volumetric efficiency: 0·876.

Effective piston displacement: (Spec. P.D. × V.E.) =6·88.

Clearance volume ratio $\left(\sqrt[1\cdot3]{C.P.\ ratio}\right)$ =5·4.

Clearance volume $\left(\frac{E.P.D.}{C.V.R. - 1}\right)$ = 1·563 cub. ft.

Charge volume: 8·443 cu. ft.

Improvements obtained: power per impulse, 9 per cent.; consumption, 10 per cent.

Load.	Impulses per min.	Gas, cub. ft. per min.	Impulses per cub. ft.	Charge volume per cub. ft. of Gas.	Mixture strength B.Th.U. per cu. ft.	Mean pressure lbs. per sq. in.	Factor: $\frac{M.P.}{M.S.}$	I.h.p.	Cub. ft. per i.h.p. hour.
Load, as found ..	67·5	46·2	1·46	12·32	40·55	87·5	2·158	202·4	13·7
Load, as left	64·7	43·6	1·48	12·49	40·0	95·5	2·388	211·8	12·36

OBSERVATIONS.—Diagrams "Load, as found" showed late firing, which was corrected by advancing ignition of both magnetos, one by one notch and the other by two notches. Anti-pulsator valves in both gas-bags were not working freely, and diaphragms were flabby. The exhaust valve was opening early and closing very late. Instructions were left with attendant to correct this.

The desired goal having been more or less nearly approached, the inspection was concluded with a final consumption test under normal shop-load, and the comparisons then made of the initial and final ("as found" and "as left") results showed exactly what improvement had been effected. A record or test-sheet was then made out in the form shown in Table I., and from this a report was drawn up and sent to the gas company for the information of the consumer. Such report was not so detailed as was the test-sheet, as the engine proprietor could not be expected to appreciate the value of all the figures upon the latter. The report therefore merely gave the comparative "as found" and "as left" figures, with a brief statement of the condition of the engine, with suggestions as to repairs, &c., required to obtain still further improvements.

To engineers, much of the information recorded on the test-sheet (Table I.) will be self-explanatory, but in order to show clearly the method by which proper comparison between the performances of each of the engines was made possible some explanation is necessary. The author's experience with internal-combustion engines has indicated that, while the strength of mixture taking part in combustion has rarely, if ever, been taken into account in authoritative trials, yet this is one of the most important matters, which should be determined in all tests. A lengthy analysis by the author in October, 1909, of the figures given in the Third Report* of the Gas Engine Research Committee of this institution showed that the influence of mixture strength upon the thermal efficiency of internal-combustion engines was of at least equal importance as was the compression ratio. From the comparisons then possible the author arrived at the following conclusions: (1) Equal thermal efficiencies can be obtained throughout a wide range of compression pressures. (2) Equal thermal efficiencies can be obtained from varying mixture strengths, provided that ignition is properly correlated. (3) By increasing the mixture strength and delaying the firing point, higher mean pressures can be obtained with little, if any, loss of efficiency, within certain limits.

Since that date (1909) the author has had many opportunities of putting the above conclusions to the test of practical work, and is more than ever convinced of their soundness. Throughout the extensive series of commercial tests alluded to in this paper, the mixture strength of the charges taken in by the various engines has been computed in terms of

* Proceedings, I.Mech.E., 1908, pages 31-5.

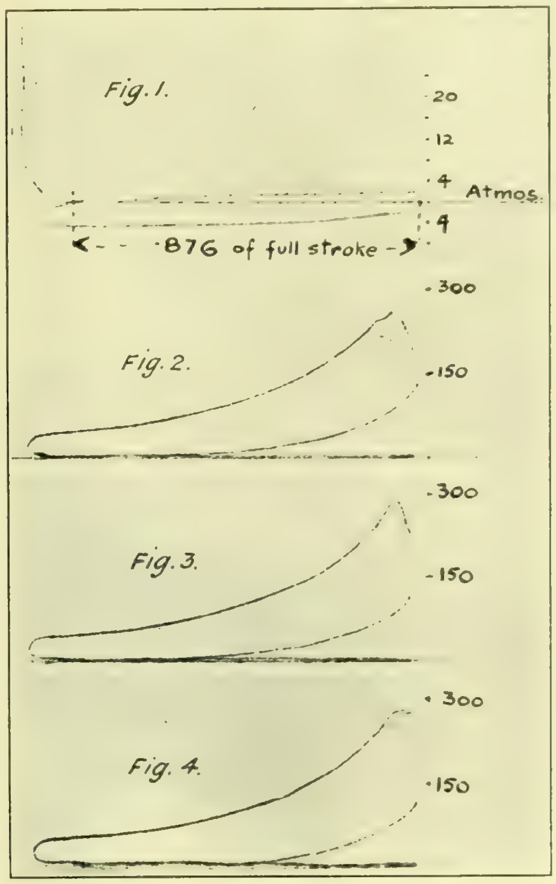
total cylinder contents, that is to say, gas, air, and residuals, and then compared with the mean pressure (positive loop) calculated from indicator diagrams. The factor $\frac{\text{mean pressure}}{\text{mixture strength}}$—thus obtained has been an invaluable aid in deciding what steps to take to obtain better performances from all the engines inspected. In order to express the mixture strength in terms of total cylinder volume, however, it is necessary to know the clearance volume as well as the piston displacement. The latter can be calculated at once from the cylinder dimensions of an engine, but the former, in commercial tests, cannot be definitely measured. A close approximation can, nevertheless, be obtained by observing the compression pressure attained and also by noting the volumetric efficiency of the engine.

Fig. 1 shows a light spring card taken from the engine referred to in Table I., and the method of determining the volumetric efficiency is there indicated. It will be seen that the point along the atmospheric line at which the compression curve crosses the latter is alone taken into account, for, at this point, it is clear that the whole of the cylinder is filled with a mixture of gas, air, and residuals at atmospheric pressure and at some indeterminate temperature. In this engine the specific piston displacement was 7·85 cub. ft., and the effective piston displacement was therefore $7·85 \times 0·876 = 6·88$ cub. ft. The compression pressure attained was 120lbs. above atmosphere, or, in round figures, 135lbs. absolute. Taking the atmospheric pressure as 15lbs. per square inch, the compression pressure ratio was 9·0, and assuming the exponent of the compression curve to be 1·30, the total cylinder volume must have been 5·4 times that of the compression volume. Therefore it can be computed that the effective piston displacement 6·88 divided by $5·4 - 1·0$, or 4·4, will give the content of the clearance space with fairly close approximation to accuracy. Thus the figure 1·56 cub. ft. is arrived at for the clearance space and that of 8·44 cub. ft. for the effective cylinder volume.

The number of impulses being noted for the various tests, as also the amount of gas registered by the meter in cubic feet, both expressed on a similar time basis, the division of the latter into the former will give the number of impulses obtained per cubic foot of gas. In Table I., for the "load, as found" count it will be seen that the figure 1·46 is thus obtained. Therefore 1·46 multiplied by the effective cylinder volume, 8·44, gives the number of cubic feet of stuff with which 1 cub. ft. of gas is mixed, namely, 12·32. If then the calorific value of the gas be known—in this case 500 B.Th.U. per cubic foot*—it can be computed that the calorific value of 1 cub. ft. of stuff in the effective cylinder volume is $\frac{500}{12·32}$ 40·55 B.Th.U. The diagram, Fig. 2, shows that, upon ignition, this strength of mixture gave a mean pressure of 87·5lbs. per square inch, or 2·158lbs. for each British thermal unit in 1 cub. ft. of the mixture. To one who is in the habit of checking the performances of internal-combustion engines in this way, the value obtained for the factor—$\frac{\text{mean pressure}}{\text{mixture strength}}$—at once indicates that the engine was doing well in respect of economy, and that, usually, no betterment can be expected under ordinary working conditions by adjustment. From the diagram, Fig. 2, however, it will be seen that the ignition was somewhat late. An attempt was made to correct this by accelerating the low-tension spark from both magnetos with which the cylinder was equipped, each lever being moved one notch forward. The result is shown in Fig. 3. Even with this acceleration, while improved, the ignition was still somewhat late, and consequently that magneto which was situated at the back end of the combustion chamber was further adjusted by moving the control lever one notch further in advance. The diagram then obtained, Fig. 4, was satisfactory, the slight variations in successive cycles noticeable at the top of the card being attributable to the irregular movements of the anti-pulsator valves in the two gas-bags provided.

The next step was to determine what effect these ignition adjustments had upon the gas consumption. The "load, as left" count was therefore taken, with the result shown by the series of figures in the lower line of Table I. The "factor" —$\frac{\text{mean pressure}}{\text{mixture strength}}$—is there found to be 2·388—a most satisfactory value. Naturally, the assumptions necessary for obtaining this factor in commercial tests will not permit acceptance of the figures as being absolutely accurate, but, being recognised as but an approximate standard of comparison, the "factor" will, for test-bed work and for general purposes, be found particularly useful. It shows very clearly whether any engine is or is not doing well, whether the mixture employed is too strong, and also what influence ignition-timing, prevailing skin-temperature of the cylinder walls, and deliberate adjustments have upon the performance of any engine under observation.

In many cases published results of tests have not hitherto included volumetric efficiency of the engines, nor has any standard been authoritatively approved of the measurement



Figs. 1-4 refer to test as Table I.

FIG. 1.—DETERMINATION OF VOLUMETRIC EFFICIENCY.
FIG. 2. M.E.P. 87·5lb. LATE IGNITION OF CHARGES, "LOAD AS FOUND."
FIG. 3.—EARLIER IGNITION IN CONSEQUENCE OF ADJUSTMENT OF BOTH MAGNETOS BY ONE NOTCH.
FIG. 4.—IGNITION OF CHARGES "LOAD AS LEFT" BY BACK END MAGNETO BEING FURTHER ADVANCED BY ONE NOTCH.

of volumetric efficiency. Usually, however, the latter has been determined by referring the length of atmospheric line between the two points where the suction and compression lines cross the atmospheric, as a percentage of the total length of the indicator diagram. This is incorrect for the purpose of computing clearance volume and mixture strength on the lines indicated in the present paper. The importance of taking volumetric efficiency into account is very marked, and particularly in connection with engines governed by throttling the mixture, as, with the same clearance volume, lower compression pressures are then attained.

In one test made by the author, a vertical gas engine, which was designed to work at 100lbs. (say, 115lbs. absolute) compression pressure, attained at maximum, normal full load, three-quarter load, and half-load, 96lbs., 92lbs., 78lbs., and 73lbs. per square inch respectively. The volumetric efficiencies at each compression pressure were respectively 88·2, 83, 80, and 76·5 per cent. Assuming the exponent η in $\frac{P}{p} = \left(\frac{V}{v}\right)^{\eta}$ was 1·30, the clearance volume at 100 per cent. volumetric efficiency for a piston displacement of 0·55 cub. ft.

* The average calorific value of gas distributed by the "ring" mains of the South Metropolitan Gas Company, into which all their stations feed, is approximately 500 B.Th.U. per cubic foot, and practically constant at that figure.

(cylinder 11in. diam. by 10in. stroke) would be 0·145 cub. ft.; and the total cylinder volume 0·695; the clearance ratio = total cylinder volume (piston displacement plus clearance), divided by clearance volume—being 4·8. At 96lbs., 92lbs., 78lbs., and 73lbs. compression pressure the clearance ratios would be respectively 4·7, 4·5, 4·05, and 3·9 ($\eta = 1·30$), and with the clearance volume common to all at 0·145 cub. ft. as before, the effective piston displacements for each ratio would be 0·535, 0·5065, 0·4410, and 0·4193—each of which are equivalent, in respect of the specific piston displacement of 0·55 cub. ft., to the volumetric efficiencies determined by the indicator. For the purpose of computing total cylinder capacities, therefore, as long as the compression pressure and volumetric efficiency are known, the compression ratio can be determined and the clearance volume ascertained therefrom, with reasonable accuracy for commercial testing, as exemplified in connection with Table I.

The compression curve exponent 1·30 appears to hold good for engines widely varying in design, within close limits. For instance, in Mr. H. Ade Clark's paper* on the Diesel engine, read before this institution in 1903, it was mentioned that the compression pressure ratio was 35 for a Diesel engine having 41·1 mm. clearance volume and 600 mm. stroke volume—that is to say, a clearance volume ratio of 15·6 (641·1 ÷ 41·1). From these figures it is evident that the exponent would be 1·294. Again, as already stated, the 11in. by 10in. gas engine, respecting which figures for volumetric efficiency at various compression pressures due to throttling have been given, gave the exponent as 1·30, while in Prof. Burstall's tests† for the Gas Engine Research Committee, assuming 100 per cent. volumetric efficiency, the terminal compression pressures attained for various clearance ratios gave a value for the exponent varying from 1·24 to 1·35, with an average of 1·30 (Prof. Burstall's remarks upon the determination of the compression curve exponents in these tests should, however, be referred to).

Other instances could be cited confirming the exponent 1·30 being in accord with compression pressures obtained with known clearance volume ratios for many different types of gas, petrol, and oil engines, and, as the Diesel engine tested by Mr. H. Ade Clark running at 160 revs. per minute, the Premier engine used by Prof. Burstall running at 170 revs. per minute, and the Browett-Lindley vertical gas engine tested by the author running at 450 revs. per minute, may be accepted as widely varying examples, it does seem probable that computations upon the exponent of 1·30 will give sufficiently accurate data for ordinary commercial testing purposes.

The author has frequently been impressed by the fact that, in the majority of scientific investigations reported to engineering societies, all references to mixture strength have been omitted. In saying this he is, of course, aware that some exceedingly ingenious methods have, on rare occasions, been adopted to determine the volume or weight both of air and of gas, or air and petrol, &c., that have been drawn into engine cylinders, in order to state the ratio of one ingredient to the other. But in practice the combustible forms part of a mixture of air, gas, and residuals, and it is probably because of the difficulty in measuring the latter that the hitherto existing lack of information is due.

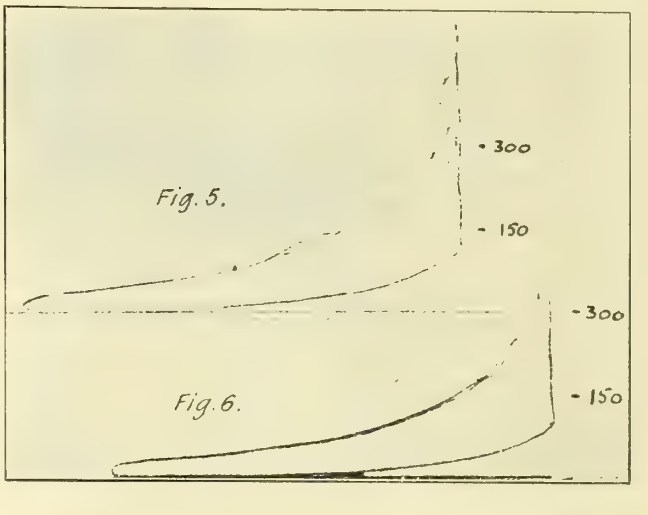
Dr. Dugald Clerk, in his book "The Gas, Petrol, and Oil Engine," Part I., 1909, refers to this in connection with Dr. Slaby's well-known experiments, and suggests that the inclusion of hot residuals makes the actual weight of mixture practically indeterminate. Yet the internal-combustion engineer, for commercial purposes, does not need to know the weight of the mixture. It will suffice if he can obtain information as to the relative mixture strength in British thermal units per cubic foot of effective cylinder volume. Knowing this, he can, by taking into account the mean effective pressure obtained, get all the information that is of practical use to him, for with this common basis of comparison experience will soon teach him how to apply such knowledge to the best advantage. In the absence of knowledge as to the mixture strength used he is absolutely in the dark, and is daily confused, in that, with one engine of a certain size coming on to the test-bed, the rated power—or consumption—

* Proceedings, I.Mech.E., 1903, page 395.

† Proceedings, I.Mech.E., 1908, page 5.

may be readily obtained, while with perhaps another engine of the same or a different batch he finds it extremely difficult to obtain the "list" figures for output or for efficiency. Without a knowledge of the mixture strength with which the engine is working—and also the mixture strength at which the engine works best—he cannot even be certain that the test-bed adjustments are final; for if, for example, when the engine is put into regular operation, an undue increase of cylinder-wall temperature occurs, the performance of the engine will be likely to cause trouble, and especially so should richer mixtures be admitted than those for which the ignition timing has been "set."

The large number of tests systematically made during the survey already referred to provides much valuable data which cannot be presented in a complete form in the present paper, but a selection of test results, taken almost at random from a number of engines of varying cylinder dimensions and compression ratios, may be presented and discussed. Table II. reproduces a portion of the test-sheet of a small gas engine. Here it was found that for "load, as found" the factor, $\frac{\text{mean pressure}}{\text{mixture strength}}$, was 1·83. The diagrams, Fig. 5, showed that "as found" ignitions were extremely rapid. The effective cylinder volume per cubic foot of gas was somewhat low, namely, 9·90 cub. ft. Therefore the adjustments made were



Figs. 5 and 6 refer to test as Table II.

FIG. 5.—"LOAD AS FOUND." RAPID IGNITION DUE TO EARLY FIRING AND RICH MIXTURE. COMPARE FIG. 6.

FIG. 6.—"LOAD AS LEFT." REDUCED SUPPLY OF GAS, CURTAILMENT OF EXHAUST PERIOD AND RETARDED IGNITION.

to retard the lead of the magneto ignition and to diminish the gas supply. Another point that the light spring cards drew attention to was the ill effect caused by the exhaust valve opening too early and closing too late; adjustment was therefore made to curtail the exhaust period. The effect of these slight alterations is shown in the "as left" diagram, Fig. 6, and in the "load, as left" line of Table II. It will be seen that 1 cub. ft. of gas then sufficed for 13·25 cub. ft. of effective cylinder volume, and the factor, $\frac{\text{mean pressure}}{\text{mixture strength}}$, rose to 2·41. So that, in this small engine of 0·1365 cub. ft. specific piston displacement per stroke, almost equivalent efficiency was obtained as in the larger engine, Table I., of nearly 60 times the cylinder capacity. It is interesting to notice the relative figures in this test when the engine was running "light, as found." With no variation due to deliberate adjustments, but consequent merely upon additional load and less frequent internal cooling by means of consecutive idle strokes or scavenging cycles, the factor of 2·133 was reduced to 1·83. It will be noticed also that, although the mean pressure was higher at "light, as found," yet this was obtained by a somewhat weaker mixture than "load, as found." That still further reduction of mixture strength was advisable to obtain higher efficiencies under the prevailing conditions is clearly shown from the "as left" factor. Incidentally, it may here be pointed out that the factor as used by the author enables an experimenter to observe, with great practical benefit, the actual variations of

mixture strength consequent upon normal variations of conditions peculiar to all internal-combustion engines, and their effect upon efficiency, &c.

Table III. is an abstract from the test sheet relating to a gas engine of about the average size in general use in London factories. In this instance it was found that the engine was working so well that no improvements could be effected. It is interesting to note that the value of the factor, $\frac{\text{mean pressure}}{\text{mixture strength}}$, is slightly higher than that noted in Table I., although the cylinder dimensions of the latter were more than seven times as great. Similarly, the factor is comparable also with the small engine in Table II., although the latter was but one eighth the size in terms of cylinder capacity.

TABLE II.

5in. by 12in. gas engine No. 53610.

R.p.m. { Light : 273. Load : 267.

Specific piston displacement –0·1365 cu. ft.

Governor : Hit-and-miss.

I.h.p. constant 0·000596.

Ignition : Low-tension magneto.

Compression pressure : 110lbs.

Volumetric efficiency : 0·92.

Effective piston displacement : 0·1255 cu. ft.

Clearance volume ratio : 5·1.

Charge volume : 0·1562 cu ft.

Load.	Impulses per min.	Gas. cub. ft. per min.	Impulses per cub. ft.	Charge volume per cub. ft. of Gas.	Mixture strength B.Th.U. per cub. ft.	Mean pressure lbs. per sq. in.	Factor : M.P. / M.S.	I.h.p.	Cub. ft. per i.h.p. hour.
Light, as found ..	47·6	0·718	66·4	10·26	48·25	103	2·133	2·92	14·75
Load, as found ..	95·7	1·5	63·4	9·90	50·25	92	1·83	5·25	17·15
Load, as left	111·8	1·31	85·4	13·25	37·75	91	2·41	6·05	13·0

OBSERVATIONS.—Engine had been recently overhauled. "As found," the mixture was too rich, involving heavy bumping on ignition. The exhaust valve was opening very early and closing after gas-valve opened. The ignition had too much lead and was retarded.

Very efficient cooling and careful adjustment of ignition-timing devices are required when engines are called upon to deal with loads necessitating a continuity of explosions producing mean pressures of the order of 90lbs. per square inch. As will be sufficiently clear from the examples already referred to, such high pressures are not at all uncommon in every-day work (the author has obtained as much as 118lbs. per square inch from an engine lightly loaded and taking a scavenging charge after each power cycle), and there is little doubt that gas engines, rated by the makers upon the basis of 80lbs. per square inch for continuous work, actually possess a considerable reserve of power; but, unfortunately, the manner in which engines can be run at such overloads is very rarely understood by men in whose charge they are placed, while, until recent years, no facilities were provided by means of which the necessary adjustments could be made to achieve this much-to-be-desired end.

The only limit to an engine's capacity for overload within the range above mentioned is the liability of pre-ignition of the charge during the final portion of the compression stroke. The more nearly the temperature reaches a certain critical point either by heat generated during compression, or by cylinder wall radiation, practice seems to promise higher efficiencies. The output of power depends upon the mixture strength the richer the mixture the more powerful the impulse, in terms of mean pressure. But if the load demands a mixture so rich that the combustion, when once started, proceeds with extreme rapidity under the temperature due to compression and wall radiation, then pre-ignitions are set up spontaneously, which announce their existence by violent bumping and quickly bring the engine to a standstill if allowed to continue.

It is for this reason that engines governed on the "hit-and-miss" system can work continuously at high mean pressures without giving trouble. Even if but one miss occurs at intervals of, say, twenty cycles, the engine will work quite satisfactorily under such conditions, probably due to the fact that the air, admitted during the "governing cycle" or "miss" in a state of turbulence, very effectively cools the skin of the internal wall below the critical temperature, which water circulation alone is not able to reduce.

TABLE III.

11½in. by 18in. gas engine No. 36553

Specific piston displacement 1·08 cu. ft.

Governor : Hit-and-miss.

I.h.p. constant 0·00471.

Ignition : Low tension magneto.

Compression pressure : 160lbs.

Volumetric efficiency : 0·935.

Effective piston displacement : 1·01 cu. ft.

Clearance volume ratio : 6·6.

Charge volume : 1·19 cu. ft.

Load.	Impulses per min.	Gas. cub. ft. per min.	Impulses per cub. ft.	Charge volume per cub. ft. of Gas.	Mixture strength B.Th.U. per cub. ft.	Mean pressure lbs. per sq. in.	Factor : M.P. / M.S.	I.h.p.	Cub. ft. per i.h.p. hour.
As found	45·14	4·45	10·45	12·08	41·4	100·5	2·43	21·4	12·5

OBSERVATIONS. Engine practically new. Temporary adjustments to mixture regulation and ignition timing resulted in no improvement, and engine was left "as found."

Pre-ignitions are much more likely to give trouble when engines are throttle governed, for, under heavy loads, the compression pressures and temperatures are higher and more heat is given to the walls; but, even then, with copious water circulation and with properly retarded ignition suitable to the load, overloads requiring upwards of 90lbs. to 95lbs. mean pressure can be carried for quite considerable periods.

The author is of opinion that, judging by his own experience, internal-combustion engine makers will find that the factor value suggested in this paper will be most useful to them in tuning up their engines. Tables can be prepared for the use of the test-bed staff which will give definite figures without calculation for effective cylinder volumes corresponding with actual volumetric efficiencies. Then, with diagrams obtained by means of correctly set reducing gear and with instruments of fair accuracy, the factor value can be calculated from the following formulæ:—

(1) $H \times F \div I \times V = S$.

(2) $P \div S = \text{Factor}$;

in which—

H Average calorific value of fuel per pound or cubic foot.

F Lbs. or cubic feet of fuel consumed per minute.

I Impulses per minute.

V Effective volume of cylinder in cubic feet

P Mean pressure lbs. per square inch.

S Mixture strength in B.Th.U. per cubic foot.

The term S will be a direct guide to the relative mixture strengths admitted to every engine, and, this being known, many phenomena hitherto held to be inexplicable will be made clear to those engaged on the test bed. With a certain setting of the gas-regulating valve or its equivalent, the standard mixture strength for which the rated powers apply can be readily obtained, and the air adjustment can then be regulated so that proper combustion ensues. With a mixture strength of, say, 40 B.Th.U. per cubic foot, mean pressures of 80lbs. per square inch can be definitely relied upon, and, given sufficiently close adjustment of ignition timing, even 90lbs. or more can be secured without risk of pre-ignition, provided that the compression pressure is not too high and the internal cylinder walls, &c., are efficiently cooled.

When it is realised, as various test sheets in the author's possession show, that mixture strengths of 50 and 55 B.Th.U. per cubic foot of effective cylinder volume can be efficiently burnt in gas engine cylinders, which will give proportionately greater power without loss of efficiency, it will be recognised

that gas engines rated on 80lbs. m.e.p. possess a capacity for overload far greater than has usually been conceded to them. To obtain this overload capacity, however, it is essential that means of control of ignition and combustion of mixture should be provided by makers. Ignition tubes with timing valves must be abandoned in favour of some form of electric ignition device that shall be adjustable. When utmost efficiency must be maintained, gas-engine drivers should be encouraged to take indicator diagrams from time to time when noting the consumption of gas, and thus to obtain the factor value. For this purpose the supply of gas to each and every engine, whether town or producer gas, should be passed through meters. The arithmetical problems are of the simplest description and can be done expeditiously.

A LARGE AUTOGENOUS WELDING PLANT.

THE Augsburg-Nuremberg Machine Company was one of the first German concerns to employ autogenous welding on a large scale; its installations for this purpose have been continually enlarged, and last spring a large special plant was installed, said to be the last word in this branch of engineering. This plant was described in a German contemporary, and we are indebted for the accompanying particulars to the "Journal of the American Society of Mechanical Engineers." Fig. 1 shows a section and plan of the installation. The carbide storeroom located near the machine room *A* is separated from the latter by a fireproof wall with a fireproof door, and has a storing capacity of 10,000 kg. (22,000lbs.). The generation of the acetylene is carried on on the so-called deep generation system, *i.e.*, with the generator direct in the water space. This system was adopted because in plants of this size a very important element is that of removing the carbide residues, and for this purpose it is well to have as large a water reservoir as possible, which can be best done with the "deep" system. As shown in Figs. A and B, the machine plant consists of two generators *c* and *c'* for 50 kg. carbide each, the washer *d* with the water-closing device *e*, a gasholder (standing in the open) of 30 cub. m. (1,059 cub. ft.) useful volume, cleaners *f* and *f'* of 0·25 cbm. (8·8 cub. ft.) useful volume, station gas meter *g* with a capacity of 31 cbm. (1,094·7 cub. ft.) per hour; Knappich central safety water reservoir *h* (more of it below); gasholder contents indicator *i*, water manometer *k*, and emergency lighting *l*.

After being generated in the generators *c* and *c'*, the acetylene flows through the washers *d*, which serve also as water seal, to the gasholder, from which, when required, it flows through the two cleaners *f* and *f'*, gas meter *g* and the Knappich safety water reservoir *h*. By these means the impurities contained in the acetylene and soluble in water, such as ammonia, hydrogen sulphide, &c., are eliminated from it at the same time that it is being generated and stored away; on the other hand, such impurities as hydrogen phosphide, hydrogen silicide, &c., are retained by chemical means in the cleaners *f* and *f'* on the way to consumption (because here the gas flows with less velocity). The acetylene therefore reaches the place of consumption in a state of technical purity, which is very important for the production of good welds.

The generator is always surrounded by a large quantity of water, which helps to obtain both an economical gasification of the carbide and a gas free of products of polymerisation (owing to the fact that the excess of water provides an effective cooling). Further, since every generator has a capacity of 50 kg. carbide and a production of 15 cbm. (530 cub. ft.) of gas, the amount of air which gets into the charging chamber with the carbide may be considered as negligible, and the formation of explosive mixtures practically eliminated.

In the cleaners, which have to take care of the impurities not readily soluble in water, a product with a chromic acid basis is used (its exact composition is not stated). The cleaners are sealed hermetically by a bell partly submerged in water and provided with an automatic alarm whistle indicating low level of the water seal.

The purpose of the gas meter is to determine the consumption of gas in the plant, as well as the gas output per unit of calcium carbide used. In addition to the gas meter, the plant uses a special apparatus (of Dr. Caro) for the determination of gas production from carbide. The water manometer is arranged so that it can be connected with any part of the plant, though as a rule it is on the generator.

The piping consists of cast-iron pipes, 100 mm. and 80 mm. (3·9in. and 3·1in.) diam.; the cleaners are provided with shunt piping, so as to prevent disturbances in the flow of gas should a cleaner become clogged. By this means the flow of gas may be regulated as desired, and the cleaners connected in parallel.

German government regulations provide that there should be a water seal at each welding stand between the gas piping and the burner to prevent backfiring into the piping when the burner tube becomes clogged, as well as to prevent the oxygen from getting into the acetylene piping. Most of the accidents which have occurred in autogenous welding may be traced back to improperly designed or improperly kept water seals. In large plants, with an extensive system of piping, there is the further danger that, with a defective water seal, the backfiring may penetrate as far as the apparatus house or gasholder, and make trouble there. To prevent this, the Knappich safety water reservoir has been installed. It is shown in

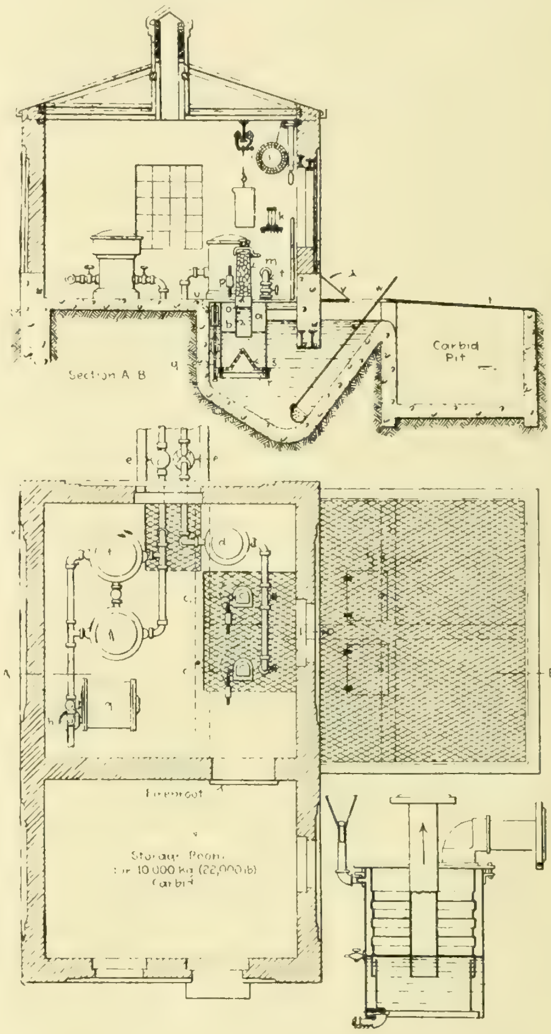


FIG. 1.—A LARGE AUTOGENOUS WELDING PLANT.

section at the lower right-hand side in Fig. 1, and its characteristic is that it is provided with an alarm whistle which acts automatically: (*a*) when the water level becomes too low; (*b*) when the welding pistol is clogged (the oxygen is then forced to flow through the alarm whistle, and produces the sound of alarm); (*c*) when, through some irregularity in the piping, air is admitted into it. This alarm whistle, which is set into motion by the kinetic energy of the oxygen under pressure, instantly and automatically indicates any error in the actions of the welder or attendants, so that they may be attended to before it is too late. One of the striking facts in connection with this plant is the small attendance required. The present plant, having an output of 300 cbm. to 600 cbm. (10,594 cub. ft. to 21,188 cub. ft.) per day, or about five times as much as would be required for the lighting of a city of 5,000 inhabitants, has only one man for its attendance. More than 50 welding burners are operated throughout the plants, from the smallest to the largest size, autogenous welding being used for the most varied purposes.

THE USE OF STELLITE IN THE MACHINE SHOP.

By Elwood Haynes.

Whenever any new material is proposed as a partial substitute for one already in use, various misunderstandings are likely to arise. Exaggerated accounts of its capabilities are likely to be given, and because of this, some of its purchasers are likely to be disappointed when it does not fulfil the exaggerated accounts. Most of the trouble, however, which arises from the introduction of a new material or new device is due to an improper understanding of its capabilities and improper application of it in practice, so that the new device or new material is likely to have a setback which it really does not deserve. This was true of aluminium, of the new abrasives, of the automobile, and of countless devices which have since won their way by sheer merit into extensive practical use.

Stellite is an alloy formed from the semi-rare metals, all of which are very much more expensive than iron, but factory superintendents are now well aware that it does not always pay to buy low-priced steel for tools simply because it is cheap. It is not the low cost of the metal in the tool that determines whether it will pay or not to buy it, but the efficiency of the tool under intelligent care and handling. Take, for example, a tool made of carbon steel; the metal in this tool may cost 5d. per pound, while the metal in the high-speed tool may cost 4s. per pound. Taking the carbon steel tool as a basis, limiting the time of operation on a given piece of work, the substitution of a high-speed tool in its place, costing ten times as much, may yield a sufficient profit to pay the increased cost of the high-speed tool within a single day or perhaps within a few hours. But in order that the high-speed tool may accomplish this result, it must be given a chance to prove its efficiency. If, for example, a machine is running so slowly that a piece of carbon steel will take the cut without losing its hardness, then there will be no advantage in using the high-speed tool, but the up-to-date manufacturer will see to it that his factory is equipped with machinery that will give the best machines a chance to do their best work.

There are four attributes which should characterise a cutting tool: (1) Sufficient hardness; (2) sufficient strength; (3) ability to resist high temperature due to cutting speed; (4) resistance to wear. The word hardness is not very well understood, since there seems to be several kinds of hardness. The chief of these are, however, abrasive hardness and elastic hardness. Thus it often happens that the scleroscope which shows the elastic hardness will indicate a greater number of degrees for a substance of comparatively low abrasive hardness than for one of high abrasive hardness. This is because a substance may be very hard and at the same time not very elastic, though usually hardness and elasticity accompany each other.

When measured by abrasive hardness, stellite tools are perhaps superior to all others, since the hardest of them will scratch almost any other metallic combination. On the other hand, they are usually not so elastic as steel tools, and high-speed steel tools are less elastic, generally speaking, than carbon steel tools. Nevertheless, the high-speed steel tool is sufficiently elastic and sufficiently strong for all practical purposes, and is usually capable of working at far greater speed than the carbon steel tool. Likewise, the stellite tool is sufficiently strong and elastic to perform its work profitably and expeditiously, when properly installed and properly applied.

It is obviously, however, only in those cases where the cutting operation is comparatively long and the time of change comparatively short that a high-speed tool can show its greatest advantage. Now the profit on a given piece of work, other things being equal, depends upon the difference between its cost and selling price. Even a small increase in production without increase of cost may result in a large increase in profits. Supposing, for example, that the net profit on a given article after all costs are paid is 10 per cent. Now, if by some means 10 per cent. more product can be made for the same cost, then the profits have increased 100 per cent. and it is just at this point that a tool of high efficiency may so greatly increase the profits of a concern that the cost of the tool becomes insignificant. Almost every other method of increasing profit, except by organisation, calls for the investment of large sums of money, often with heavy interest charges and lack of dividends. The return from the small tools is immediate and tangible.

Perhaps no better idea can be gained of the practical value of stellite in the machine shop than by a few actual illustrations. In a certain factory a steel tool had been used for cutting off gear blanks from a 3in. round nickel steel bar. The operator, by using a soap solution on the tool, was able to cut off one blank in 8½ minutes. A stellite tool was substituted for the steel one, and he was able to cut off a blank in just a little over 4 minutes, and in the actual day's run he cut just twice the number that could be cut off with the steel tool. The stellite tool cut off 600 blanks without regrinding, while the steel tool required grinding several times per day. In the same factory an operator was able to turn 60 pistons per day with a steel tool, but by substituting a stellite tool for the steel one, he was able to turn from 90 to 100 per day. These pistons were afterwards annealed and then a finishing cut was taken from each. This finishing cut was made in half the time with a stellite tool than was required by a steel one. In facing engine cylinders a large milling machine was able to face off eight cylinders per hour with inserted steel tools. The steel tools were replaced with stellite, after which the machine faced regularly 16 cylinders per hour.

Generally speaking, the best results are obtained by using stellite for comparatively light cuts, moderate feed, and high speed. For example, a stellite tool was able to turn a piece of tool steel, containing 1·25 per cent. of carbon, under the following conditions: Depth of cut $\frac{1}{16}$in., reduction of diameter $\frac{1}{8}$in., feed 55, surface speed 180ft. per minute. During this process the point of the tool became distinctly red after cutting the first 2in., and remained so until the end of the cut, which was about 6in. in length. The edge of the tool was not injured in the slightest degree by this overheating. There was absolutely no measurable loss in the diameter of the bar. The turned surface was very smooth and uniform. The tool used in this operation was extremely hard and rather brittle, in fact, it was somewhat difficult to grind it to a smooth edge, so a whetstone was used for giving smoothness to the cutting edge. It seems remarkable that the tool would hold so perfectly while cutting the steel, and it is probable that its edge was toughened somewhat by the increased temperature produced by the turning.

In regular practice tools are now made nearly as hard as the tool mentioned, which will take a fairly sharp cutting edge directly from the emery wheel. There was some difficulty in the beginning due to the likelihood of stellite tools breaking in use. This has been largely overcome: (1) By increasing the strength of the metal; (2) by making sure that the hole in the tool holder is perfectly smooth and uniform, particularly on the bottom.

Some of the first samples of ⅜in. square stellite tools would stand from 400lbs. to 600lbs. transverse pressure at a point 1in. from the holder. They are now required to stand at least 1,000lbs. under the same test, and some of them have stood as high as 1,800lbs. without breaking. In fact, the breaking of a stellite tool is now becoming very unusual, particularly if proper precautions are taken. From the tests recorded above it is evident that very great pressure can be sustained at the end of a ⅜in. square tool, projecting as it usually does only about ½in. or even less from the holder.

It should be distinctly remembered that stellite is not a steel and it is no more logical to call it by this name than to call brass or copper or diamonds steel. Steel is a compound of iron with other materials, and iron is always the predominating and essential constituent of all steels. Stellite is composed of the metal, cobalt, alloyed with other substances, and contains no iron. The name, stellite, is derived from the Latin word, stella, a star or strewer of light, and has no reference whatever to the word steel. It was given this name because when the alloy is polished, it retains its brilliant lustre under all atmospheric conditions.

It must not, therefore, be confused with the so-called cobalt steels, which are alloys of iron or steel with cobalt and other metals. My own experiments have convinced me that the introduction of iron into stellite is always detrimental. The stellite machine tools can neither be forged nor hardened. If they were affected by heat they would lose their hardness when raised to a high cutting temperature. If they could be forged, it would be necessary for them to soften at a high

temperature, which would, of course, destroy their cutting edge. Hence they are cast as nearly as possible into the desired form, then finished by grinding.

Owing to the comparatively expensive materials used in making stellite, its cost is considerably higher than even the highest priced high-speed steel. In some cases, for example, in turning hard cast iron with a ⅝in. square bit, it has been found in actual practice that the stellite tool costs 1½d. per day, while the steel tool doing only half the work costs 3d. per day, the wear on the steel tool being more than ten times as great as on the stellite tool. But even if the cost of the stellite tool were four or five times as great per day as that of the steel one, there are numerous instances in which it would pay well to use the stellite.—"The Iron Age."

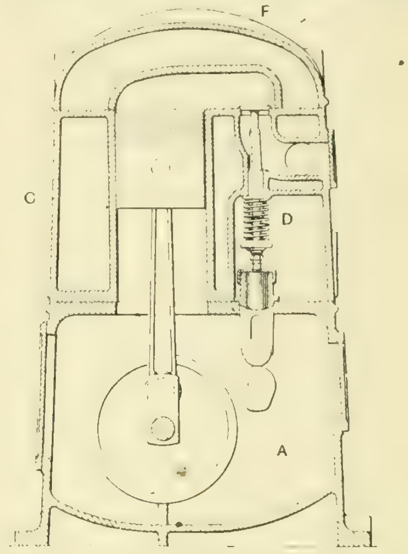
PROCESS FOR WORKING FOUR-STROKE GAS ENGINES.

A PATENT recently granted to Messrs. Ehrhardt & Sehmer, of Saarbrucken, Germany, relates to a process for working four-stroke cycle internal-combustion engines, in which water is injected into the compression chamber during the compression period, in order to cool the compressed mixture and to lower the pressure at the compression end. The injecting of water is in itself known. Thus, for instance, processes have been described in which water is injected into the cylinder during the compression stroke. This was done however less for the purpose of reducing the pressure at the compression end than for reducing the explosion temperature and thus protecting the cooling jacket. Processes for increasing the output by means of compressed air scavenging and compressed air charging are also known. The invention combines these known processes to create a new process which produces new effects. It is also known to spray water into the cylinder during the suction stroke in four stroke cycle engines which are scavenged and charged with compressed air, in one case mixed with the fuel, in quantities varying with the speed of the engine; but in such cases it was difficult to obtain complete vaporisation of the water, so that only a slight cooling was obtained. Moreover, the presence of condensed or unvaporised water in the cylinder caused mechanical difficulties. When the water is injected during the compression stroke, as in the new process, the compression temperature has risen above the vaporisation temperature of water so that the whole of the injected water is immediately vaporised. Thus, it is claimed, no water can be present in the liquid form in the cylinder, while the contents of the cylinder are cooled in strict proportion to the amount of water supplied. With the new process the parts of the driving gear do not require any strengthening, as the explosion pressures remain approximately the same at all loads. The increase of weight of the charge does not necessitate any increase of the charging space, and in that way all the advantages of compressed air scavenging and compressed air charges of all engines are fully retained. The process is carried out by increasing the quantity of water injected, with the increasing output of the engine, that is to say, with the increase of the pressure of the charge introduced during the suction stroke. In spite of the increasing weight of the charge, the compression line will not be higher, but will remain approximately the same, or even sink. Without changing the compression chamber, this combined process gives an approximately constant explosion pressure. The process for increasing the output by means of compressed air charging and scavenging can then be applied in old engines without altering the compression chamber.

Boiler Shop Plant.—At a meeting of the Glasgow and West of Scotland Association of Foremen Engineers and Draughtsmen, recently held in Glasgow, a paper on "Boiler Shop Plant" was read by Mr. John C. Wylie. He gave briefly a comparison of different types of equipment for the power-house, with the relative cost of the installations. The various machines and plant utilised in different stages of boiler construction were dealt with and comparisons made between alternative methods. The extended use of the oxy-acetylene processes of welding and cutting was advocated for work in which structural strength was not a primary consideration. Air-compressing machinery and pneumatic tools were also considered in their relation to boiler work. The paper was illustrated by slides showing typical machines by a number of leading machine tool makers.

HINDLEY'S ENCLOSED INTERNAL-COMBUSTION ENGINE.

WE illustrate herewith an arrangement of internal-combustion engine, the invention of Messrs. Hindley & Sons, Bourton, Dorset, in which the whole of the working parts are enclosed. The base A is formed of one hollow casting which provides a chamber to receive the crank shaft and associated mechanism, and manholes are provided to permit access to the interior of the base. A removable end-plate is also provided at one end and through this the crank shaft extends, and on such extending portion is mounted the flywheel. Secured on the base is the cylinder section C within which are the cylinders surrounded by a water-jacket space. The outer walls of this section are carried out on all sides to meet and fall in line



HINDLEY'S ENCLOSED INTERNAL-COMBUSTION ENGINE.

with the general contour of the walls of the base A and enclose the valve mechanism D. On this section faced lugs are provided at the points where the inlet and exhaust passages are carried out to the surface of the casing, and to these lugs connection is made for the conduits for the gas or explosive mixture, and for the exhaust respectively. Secured to the top of section C is a cap F which fits over the cylinder heads and is secured by bolts. This cap is domed at the top and the sides are shaped to lie flush with and constitute continuations of the walls of the section C. The casing is made sufficiently large to accommodate the governor and ignition mechanism.

High-speed Steel Alloys.— A lecture on "Some Notes on the Theory of Tungsten and Molybdenum Steels," was recently delivered by Mr. Thomas Swinden, D.Met., before the Sheffield Engineers and Metallurgists Society. The importance of this subject, the lecturer remarked, would be realised when it was remembered that tungsten and molybdenum formed the chief active alloys in high-speed steels. Very little work had been done to arrive at a definite theory to explain the action of these elements by virtue of which high-speed tool steel could be worked until the nose of the tool was at a dull red heat, without losing its properties of cutting metal. The lecturer dealt with two series, viz., pure tungsten steels and pure molybdenum steels. A considerable amount of data was presented by means of heating and cooling curves, which revealed the temperatures at which the physico-chemical changes within the steel took place, accompanied by tests of electrical resistivity, analysis of separated carbides, and microscopic examination of heat-treated specimens. He contended that theories based on the existence of a carbide of molybdenum were not borne out by experiment, and suggested a hypothesis that the carbon existed as iron-carbide in the annealed steels with molybdenum probably existing as a solid colloidal solution of an iron-molybdenum compound of iron. By heating the steel to beyond a certain minimum temperature, the state of existence of molybdenum was changed in such a manner as to suggest its being present as a simple solid solution of the iron-molybdenum compound in iron. It was the solution of carbon in this matrix which had the remarkable properties so well known in high-speed steel.

THE USE OF OIL FUEL IN MARINE BOILERS.*

BY JAMES S. GANDER.

(*Concluded from page* 47.)

The Direct-pressure System.—With the invention of Körting's burner, many years ago, begins the era of the direct-pressure burner. A drawing of this burner is shown in Fig. 3. Shortly after a successful direct-pressure system was

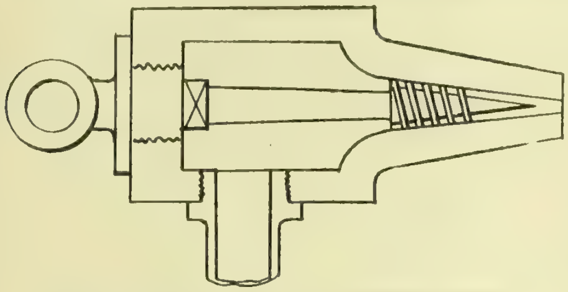


FIG. 3. KÖRTING'S FIRST DIRECT-PRESSURE BURNER.

invented by Mr. R. A. Meyer, and was installed in the vessels of the Koninklijke Paketvaart Maatschappij, of which company Mr. Meyer was at that time the superintendent engineer. The direct-pressure system is so called because the fuel is injected into the furnace by pressure from a fuel pump through a burner which is pierced at the end by a very minute hole. The fuel is heated and filtered before it arrives at the burner. Fig. 4 shows a simple arrangement suitable for a donkey boiler. As in the steam with oil system, the same precautions must be observed with regard to cleanliness of bunkers before loading and elimination of possible water afterwards. The oil being fed from pumps, there is no need for a gravitation tank, but a tank should be supplied for the separation of water from the oil—this is not an absolute necessity, but a decided advantage.

The pumps controlling the fuel pressure and supply are situated in the engine-room convenient to the front platform. These pumps, of which only one is worked at a time, draw the oil direct from the bunkers or the separation tanks through a suction heater, and discharge through a delivery heater and filter to the burners. With the Meyer system, which is probably the most up-to-date and economical direct pressure system, the filters and heaters are in duplicate, and are arranged to run separately or in couple, as desired. It is advisable to change over the pumps every week, just as would be done in the case of any duplicate pump, to keep both in thorough working order. Suction and pressure gauges are fitted to the pumps, and a large air vessel maintains regularity of pressure.

Steam for the heaters is supplied from exhaust of the pumps or direct from the auxiliary steam line, and the exhaust from the heater may pass through a separate coil in the main condenser or through a small auxiliary condenser circulated from the main pumps. The condensed water is led to an open tank divided into separation compartments, so that, in the event of any oil being present in the water, it is not possible for such oil to enter the feed supply. Leaving this tank, the water is led to the main feed tank. The filters for an installation of this type are about 4ft. in length—a brass frame covered with copper gauze of about 30 mesh. Under normal conditions the filters may be safely run for a fortnight before changing over to the duplicate. The heater coils should be cleaned every three months, and more often if water has been present in the oil, as this tends to form a slight scale at the bottom of the coils which reduces their heating effect. The construction of heaters and filters is such that the operations of examination and cleaning are easily and quickly effected. The heaters should be fitted with small drain cocks, as it is in this part of the system that we can thoroughly eliminate any trace of water in the fuel.

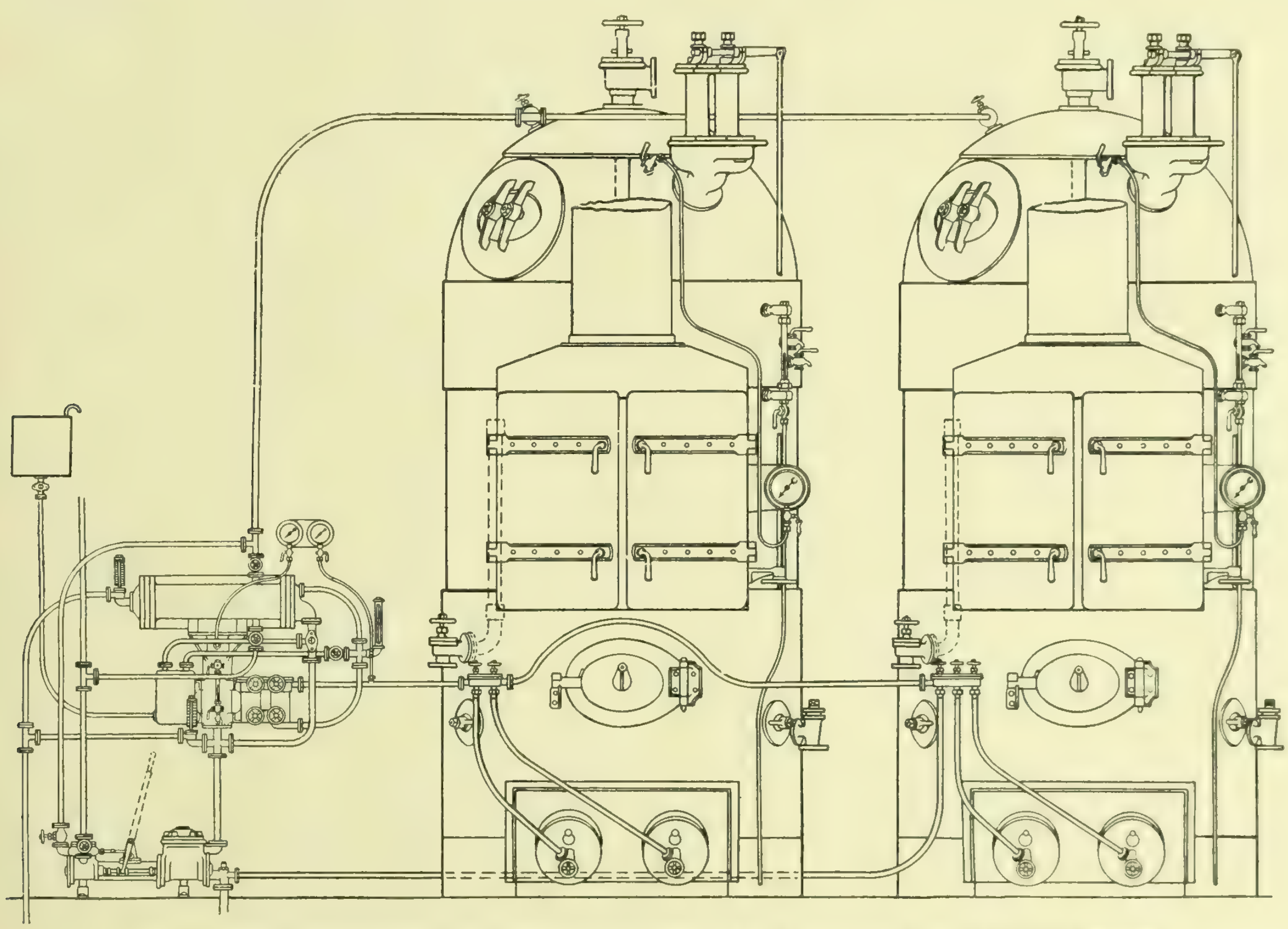


FIG. 4.—TYPICAL DONKEY BOILER INSTALLATION, SHOWING COMPLETE OIL FUEL SYSTEM FOR TWO COCHRAN BOILERS.

With the direct-pressure system it is very necessary to drain off water and filter the oil before it passes to the burners. If proper attention be given to this matter no trouble will be given by burners choking or by defective combustion in the presence of water. It is remarkable how long these burners will run without attention and cleaning, when we consider that the orifice is so small that little more than a pint passes through in one minute under a pressure of 30lbs. per square inch. A special needle is supplied for cleaning

* Paper read before the Institute of Marine Engineers, December 15th, 1913.

the orifice in the burners, and a testing apparatus enables the engineer to test the burners before fitting them in position on the furnace. The simple attachment of burners to the distribution boxes renders the matter of cleaning or renewing a very easy job. The triple thread which is cut at the end of the internal needle imparts a spiral motion to the passing oil which tends to keep the orifice scoured and also assists in the atomisation.

The temperature at which the oil will give the most economical results depends upon its nature and gravity. An average mixture of fuel oil will require to be heated to about 160° Fah., Tarakan crude to about 120°, and some of the heavier European residue to as much as 240°. All other things being equal, the correct adjustment of temperature and pressure are most important items in the efficient working of the direct-pressure system. This is a very simple matter. If the oil be too cold the spray will enter the furnace without igniting, if too hot the same will ignite as it leaves the orifice. With the correct temperature the flame should appear at little more than 1in. from the burner. The best results are obtained with a fuel pressure of from 30lbs. to 40lbs. The colour of the flame gives the same indications as in the steam and oil system. With double-ended stokeholds, and consequently long leads of fuel pipes, a small additional heater may be fitted to the fuel line most remote in order to maintain an equal temperature to all the supply. If the piping is so arranged so that an efficient circulation of the fuel takes place this is not necessary.

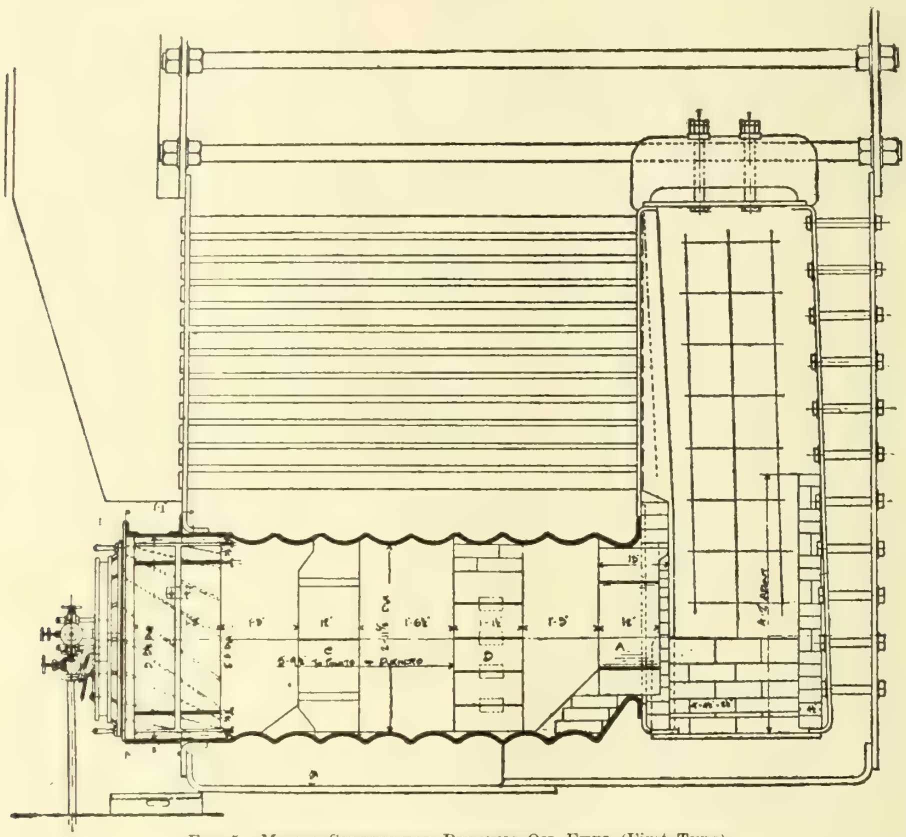


FIG. 5.—MEYER SYSTEM FOR BURNING OIL FUEL (First Type).

The construction of the furnace fronts and the air rings are a distinguishing feature of the Meyer system, and a description of the first type will enable the recent improvements in the latter to be more readily appreciated. "In the front ring (Fig. 5) of the furnace is fitted an annular ring B fitted with metal strips C secured edgewise upon and around its external surface so as to traverse it longitudinally, an interval space being left between each strip. These spaces form air channels to conduct the air, which is heated by the fuel burning inside the ring. To delay the incoming air more or less in these channels, so as to give it ample opportunity to receive the heat, the strips are arranged so as to traverse the perimeter spirally. The ring is made in two or more short lengths, so as to facilitate its manufacture, the different lengths being kept somewhat apart, thus forming circular openings through which part of the air enters and ignites the fuel inside the apparatus. The rest of the air comes in contact with the fuel on emerging from the end of the channels D. The annular space formed by these channels, by which the air enters at the stokehold side, is provided with a suitable damper, properly guided and rendered adjustable, so that the amount of air entering can be nicely regulated. Inside the annular part of the arrangement for air inlet the conductor ring is closed at the stokehold side by the cover G, which is made in two pieces, the fixed part carrying the injectors, the loose part giving opportunity for inside inspection of the furnace." Fig. 5 shows the brickwork arrangement for this type. Special attention should be paid to the removal of carbon deposits from the brick ring, and a light slice, as described previously, should be employed. Too heavy a slice in the hands of a careless operator may destroy parts of the brickwork. For the regulation of fuel temperatures thermo-pockets are fitted in the pipes at the heaters, and on each furnace front. The temperature can be raised or decreased all round the system in a few minutes. Before lighting up, the oil should be circulated round, furnace front dampers opened a little, and the fires ignited at the temperature which previous experience of a similar grade of fuel advises.

The direct-pressure system on the Meyer principle has quite recently been greatly improved. Formerly, the furnace fronts were of the heavy cast-iron type, and were somewhat cumbersome when changing from coal to oil, or vice versâ. These are now made of sheet steel of an improved design, with the result that the operation of changing over is greatly simplified. The new type (Fig. 6) embodies all the advantages of the old, the incoming air is heated, and has a rotary motion imparted to it by the retarding vanes. To carry out the idea of reducing weight to a minimum, the damper construction has been simplified and the internal vanes in this part dispensed with. The initial heating effect on the air supply may possibly be less with the new type of front than with the old, but this is compensated for by the improved and accelerated rotary motion obtained. In the writer's opinion, apart from the question of the reduction in weight, the chief advantage of the new furnace front lies in the fact that the incoming draught is directed by the conical inside baffle and enters the furnace about the centre, and not at the sides. In practice the flame appears to cover and enwrap the whole circumference of the furnace, and by admitting the heated air at a point near the centre of the furnace instead of at the sides, as in the old type, contact of cool air with furnace sides is rendered impossible.

With the new system, or the Meyer-Smith system, as it appears to be called, certain changes have been made in the construction of the burner. In the old type shown in Fig. 5 the needle was not adjustable, the quantity of oil passing depending entirely on the diameter of the orifice and the fuel pressure. With the latest type of burner an external thread is cut on the triple thread at the end of the needle, and by turning the small handwheel, which is fitted to the other extremity, the needle may be advanced towards or withdrawn from the orifice. This operation alters the shape of the spray. Once the correct shape is struck—a matter of a few seconds—the needle is left in that position. An important addition also to this burner is the small filter which fits over the needle and arrests any impurities which may have passed the main filters. With the Meyer-Smith system the furnace brickwork is dispensed with. The only brickwork used with this system is the back-end wall at the neck of the furnace, which limits the area of the opening to the combustion chamber and protects the adjacent seams, and the usual wall around the combustion chamber to cover stay nuts and seams. Comparing the Meyer with the Meyer-Smith system, the latter possesses the following advantages: Quicker handling of the furnace fronts in changing from coal to oil; improved rotary motion imparted to the fires; dampers more convenient of adjustment; cheaper first cost and renewals (according to makers' claims).

The oil fuel may be burnt with the ordinary coal fittings

in position, with forced or natural draught, on the Zulver system. This method was introduced by Mr. C. Zulver, who has installed this system in some of the vessels under his superintendence, with remarkably economical results. The burners used are of the ordinary Körting or Meyer type, but are somewhat longer for forced than for natural draught in order to bring the orifice of the burner to the correct position with regard to the furnace mouth. A further point in favour of this system is the fact that the same heating area is used for coal as for oil burning, and it is especially suitable for boilers with furnaces of large diameter, where some difficulty might be experienced in getting the whole area of the furnace to act as a heating surface. Although the heat may be said to be to some extent looal, yet it is, to coin a paradoxical term, locally distributed. Figs. 7 and 8 show the arrangement, and the simple manner in which the change from coal to oil, or vice versâ, can be effected under these conditions. It is convenient, as the labour of replacing firebars, &c., is saved. By adopting this method a vessel could be converted in a few hours. On the s.s. "Havre" the system has been changed from oil to coal burning in two hours.

When burning oil with forced draught the fan should be run as low as possible consistent with good combustion, otherwise heat is being blown up the funnel. With forced draught, as with any other fuel system, it is always possible to run without smoke. It is good practice to obtain a slight smoke at the funnel with both the steam and the forced-draught systems. In the first case we are not wasting steam, and in the second not using too much draught. A water column of $\frac{5}{8}$in. to $\frac{3}{4}$in. in the ashpit gives good results, but each vessel has its own peculiarities, and the best pressures must be obtained by trial. The usual fuel pump pressure would be from 35lbs. to 45lbs., depending on the fuel. As shown in the diagram, the firebars are bricked over, with the exception of a strip at the front end through which the draught passes upwards from the ashpit. The addition of a small retarding block placed about 2ft. from the furnace neck effects a slight economy in some cases. Observation mica discs enable the state of the fire to be examined without losing draught. A small door is fitted to the furnace door to allow of the insertion of the carbon slice. As there is no occasion to open the firedoor it is made air-tight with asbestos putty and clamped up. The burners are asbestos packed where they enter the doors, and cleaning is easily effected by means of the plug at the back without removing the burners from the doors. As in all forced-draught jobs, the vertical air heating tubes should be periodically examined and cleaned.

In an oil-burning vessel there is sometimes a tendency to allow the smoke tubes to run a considerable time before sweeping. Although the quantity of soot found after a long run is very minute when compared to that which may be expected from a coal-burning job, yet, as the insulating properties of oil soot appear to be slightly greater than those of coal soot, it is good practice to clean the tubes once a month.

With the direct-pressure system of the Meyer type, when no steam is available for starting fuel pumps, it is necessary to inject the fuel at the commencement with a small hand pump—usually a hand lever is fitted to the motion arm of the ordinary fuel pump—and the oil passes through a coil heated by a kerosene blow-lamp or burner. This very seldom happens, as, in the case of all fires being out of action, shore steam or compressed air is generally supplied to carry on the ordinary work of the engine-room. With the steam with oil system and no steam or compressed air from external sources available for starting, the oil is sprayed on to a small wood fire inside the furnace by the force of its own gravitation In this respect the direct pressure system is preferable.

When raising the temperature of the fuel oil on direct pressure systems the exhaust valve of the heating coils should not be opened too much if it is required to heat the oil to a high degree. If the valve be almost shut down the pressure in the coils will be nearly the same as the initial supply, with a correspondingly high temperature, and the heating effect can then be regulated by the amount of opening of the steam valve. On the other hand, if the exhaust be too much open the pressure in the coils will be nearly the same as that of the exhaust line, or almost atmospheric, with a temperature which will not serve to heat the oil beyond 200° Fah. In extremely cold climates and with heavy-grade fuel a little difficulty may arise owing to the thickening of the fuel interfering with the working of the pump. This is provided against by the addition of a small heating coil to each of the

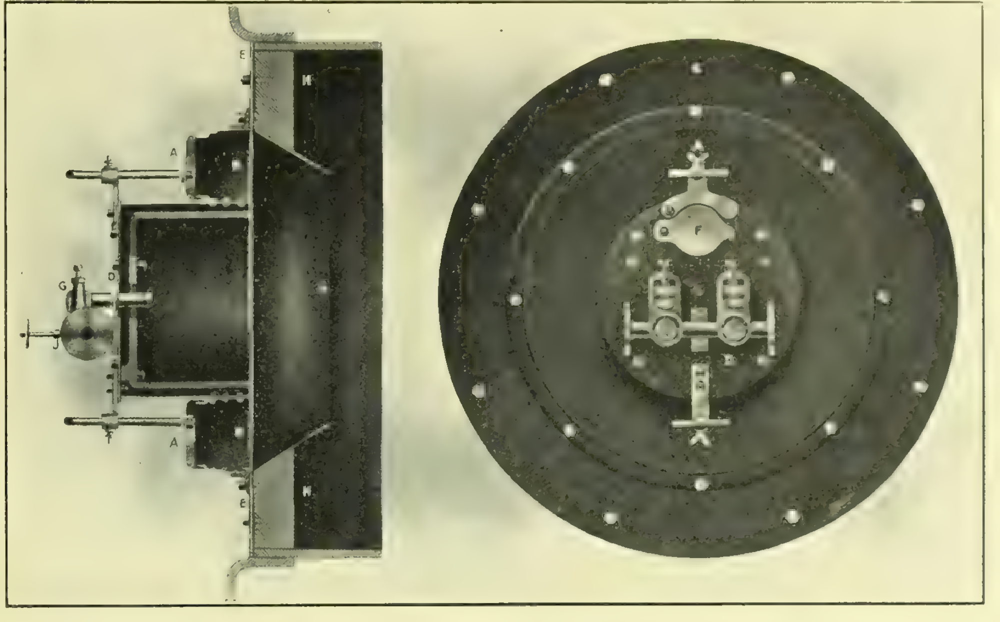


FIG. 6.—THE NEW "MEYER-SMITH" PATENT FURNACE FRONT FOR OIL FUEL.

A, circular sliding damper controlling air supply through inner heating passages C. B, circular sliding damper controlling air supply through outer heating passages D. C, air passages with spiral vanes for heating and imparting rotary motion to air entering furnace to ensure complete mixing with oil spray. D, outer air supply and heating passages. E, steel plate cone to form heating passage and direction plate. F, flat steel extension plate to fit furnace mouth. G, front plate of furnace to which burner boxes are fixed. H, observation and lighting-up door. J, burners complete with gun-metal distribution box.

suctions in the bunkers, so that when occasion arises a little steam may be passed through, which has the effect of raising the temperature of the surrounding oil.

The previous remarks with reference to cleanliness of bunkers, separation of water, and efficient filtrations, apply to all modern oil-burning systems as well as to the steam with oil system, under which heading they were included. The steam burner and other similar types, having a large opening for fuel with a low velocity, are much less sensitive to the presence of water or impurities.

Much has been said at various times with regard to the supposed risk attending the consumption of oil fuel in marine boilers. Although it is recognised in these days that oil fuel is a perfectly safe factor for the generation of steam, the safeguards against possible accidents are very thorough. Among these are the following: (*a*) Ash cocks are fitted with lengthening rods so that they may be operated from the deck or the stokehold; (*b*) sand boxes are provided in each stokehold; (*c*) water hoses are in readiness in prominent positions; (*d*) the steam supply to fuel pumps can be shut from the deck or below; (*e*) regular inspection and the washing of stokehold plates each watch.

Experiments show that water is infinitely more effective than any other practicable agent in the quenching of burning oil fuel. It immediately lowers the temperature, with the result that the fuel can no longer burn In an experience of

five years of continuous oil-fuel burning the writer has not seen a fire occur; it is simply a matter of the observance of ordinary precautions.

Comparing the steam with oil and the direct-pressure system, the advantages are greatly in favour of the latter, especially for marine purposes. Although the steam system is very simple and easily worked by firemen of average intelligence, and the cost of installation must be comparatively small, yet the direct-pressure system is far more economical of fuel. Of direct-pressure systems the Meyer-Smith, by reason of the recent improvements which have been mentioned before, appears to hold the foremost place for economy and convenience.

Speaking from the practical standpoint of the marine engineer, the following advantages are obtained from the use of oil fuel: (*a*) The quantity of bunkers received can be accurately ascertained very quickly. Tallying while taking bunkers no longer necessary. No trimming. (*b*) No cleaning of fires required—therefore no currents of cold air enter the furnace which may cause damage. (*c*) Full and regular steam can be maintained without any trouble in all climates. (*d*) Steam is under perfect control. On receiving an order by telegraph the engineer can increase or decrease the steam supply to the fuel pump without leaving the engine-room. (*e*) More perfect combustion with oil than with coal, hence greater calorific efficiency. (*f*) The engineer, if necessary, is independent of his firemen. (*g*) The boiler tops, bilges, and all engine-room and stokehold spaces can be kept in an absolutely clean condition, and there is no smoke or fumes to discolour paintwork, or ashes to choke bilges. (*h*) Combustion not affected by heavy weather. At times when coal firing might become impossible the oil-burning vessel can carry on as under normal conditions, and the bilges are always clear in the event of a wash-out. (*i*) If worked in an intelligent manner oil fuel is practically smokeless.

Comparing the systems, it is apparent that the most economical appears to be the Zulver system, with forced draught, so far as practical and reliable data are obtainable at the present moment. Reliable data with reference to the latest Meyer-Smith system have not yet been formulated, but, so far as we have been able to observe, there is a decided economy over the older type of furnace front, although the advantages of the new pattern burner are not yet so apparent in some vessels as might be expected.

S.S. "DONAX."

Particulars of diagrams taken on passage from Kustendje to Alexandria, October 19th, 1913.

Diameter of cylinders: H.P. 25in., M.P. 41in., L.P. 66in., Stroke 45in., Expansion H.P. 27in., M.P. 27in., L.P. 24in.

Pressures: H.P. 177lbs., M.P. 58lbs., L.P. 15lbs., Vacuum $25\frac{1}{2}$in.

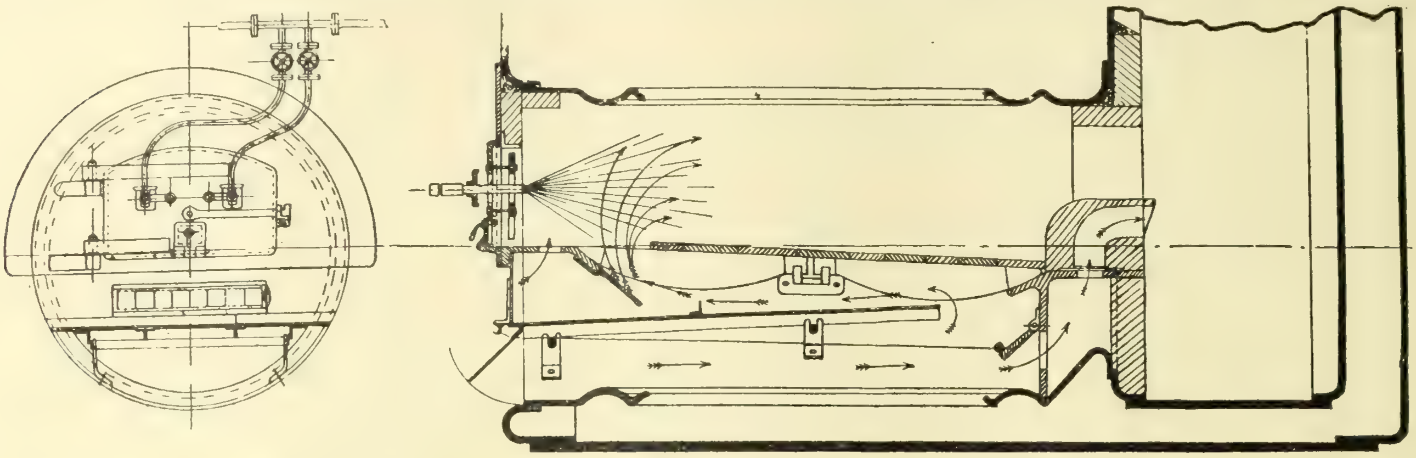


FIG. 7. ZULVER'S FURNACE ARRANGEMENT FOR BURNING LIQUID FUEL AND COAL. NATURAL DRAUGHT.

Pitch of Propeller: 16ft. $1\frac{5}{32}$in.
Speed of Screw: 11 knots.
Slip: 3·8.
Revolutions per mile: 377·7.
Speed of ship: 10·6 knots.
Revolutions per minute: 70.

Main stop valves, full speed. Throttle valve, full open.

I.H.P. 590 H.P.
,, 520 M.P.
,, 652 L.P.

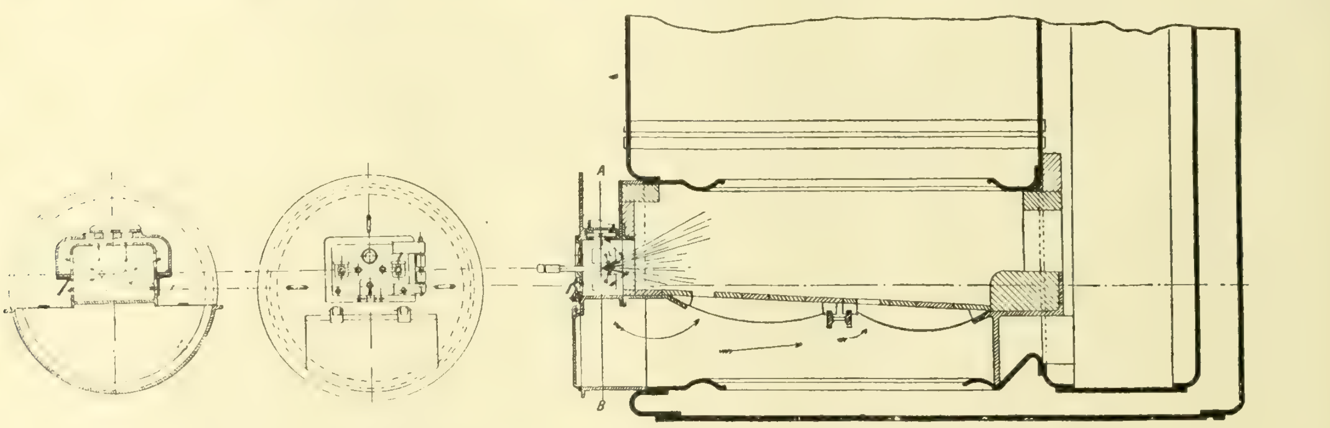
Total I.H.P. 1,762

Oil per day, 17 tons. Pounds per i.h.p. per hour, ·89 lb.
Quality, good Roumanian.
Pounds per i.h.p. per hour -Propelling power, ·83.
Temperatures: Sea 70°. Air 65°. Feed 216°. Discharge 118°. Hot well 126°. Condenser 135°. Heater 222°. Stroke Weir's Pump 8 per minute.

Fan Engine: Revs. per minute 298. Air in trunks 2in. Air below bars $\frac{9}{16}$in.

Fuel Plant: Temperature of Oil 190°-200°. Pressure 60-70lbs.

Smoke Light Haze. Weather, &c. Wind N.E. moderate. Sea moderate. Barometer 29·92. Loaded.



Section at AB. Front Elevation. Longitudinal Section.

FIG. 8.—ZULVER'S FURNACE ARRANGEMENT FOR BURNING LIQUID FUEL UNDER FORCED DRAUGHT.

The table below gives a comparison of three vessels fitted with different systems:—

	"Clam."	"Conch."	"Donax."
Cargo carried in tons	4,400	6,830	4,950
Indicated h.p.	1,111	1,760	1,767
Tons oil fuel per day	17	22·5	17
Tons coal per day (North Country)	25	33·5	27
Lbs. oil fuel per i.h.p. per hour	1·43	1·19	0·89
Lbs. coal per i.h.p. per hour	2·09	1·77	1·42
	Steam.	Meyers old type.	Zulver type with F.D.

It should be mentioned that the "Clam" is a very old type of vessel, and is not fitted with independent feed pumps, and the newer feed-heating appliances, while the other two vessels are so equipped. The "Clam" and the "Murex" are of the same type, and give the same average results.

So far as the marine engineer is concerned, the comparisons of the various consumptions per pound of oil used per indicated horse-power do not satisfy. One vessel may be fitted with the latest feed-heating and superheating appliances, &c., while the others may be of an older type,

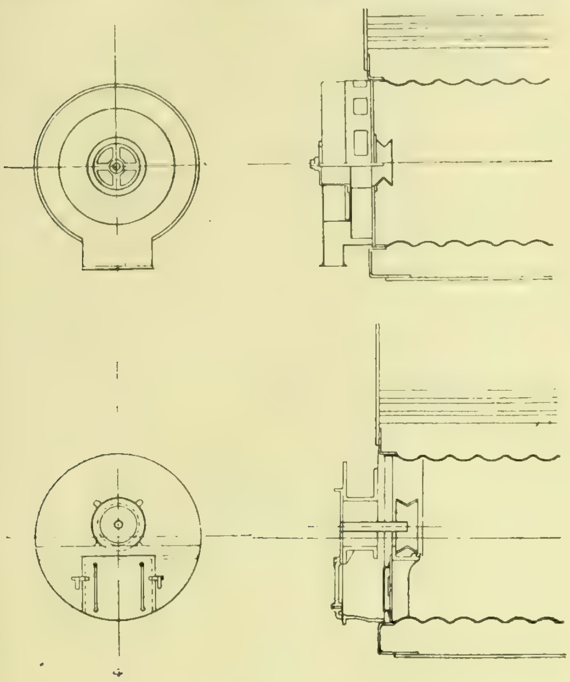


FIG. 9.

possessing none of these advantages. If we consider, however, the amount of oil burnt per indicated horse-power per hour compared with the amount of coal burnt for the same power, the other conditions cancel out from both sides of the equation, and we are enabled to ascertain whether or no the oil fuel is being economically burnt. An average result gives the ratio of coal burnt to the weight of oil burnt for the same power as 3 : 2. This means a saving by weight of 33 per cent., and shows oil fuel to be 50 per cent. more effective. This does not agree with the respective calorific values. Taking average British coal with a value of 14,000 B.Th.U. and average fuel with 19,000 B.Th.U., the efficiency advantage should be about 36 per cent. The added efficiency which is obtained in practice is due to the more complete combustion of oil fuel.

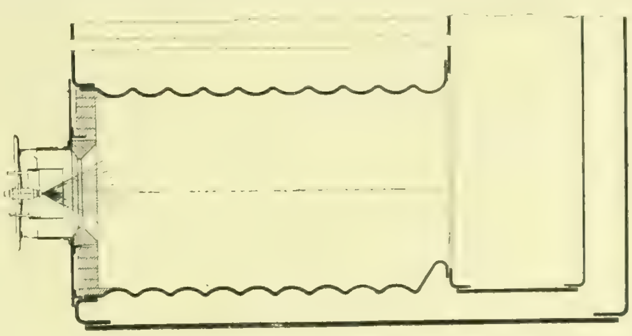
From the details of a test taken at the works of Smith's Dock Company we gather some valuable information relating to temperatures which are not easily obtainable at sea. Dimensions of boiler 8ft. 9in. by 8ft. 6in., with two plain furnaces 31in. external diameter, 6ft. 1in. long; total heating surface 470 sq. ft. Meyer-Smith system used.

		Deg. Fah.
Temperature of air		54
" in passages round air conveyer in furnace fronts through which the air passes to furnaces		870
" of furnace		2,375
" of combustion chambers		1,280
" of smokebox		580
" of feed water		120
" of oil in heaters		220
Pressure of oil to burners		35
" steam on boiler		80
Consumption of oil per hour	lbs.	164·35
Total water evaporated per hour	"	2,592·51
Water evaporated from and at 212° Fah. per lb. oil used	"	15·7
Brand of oil used—2 parts Texas, 1 part Borneo.		
Specific gravity		·944
Flash point	deg. Fah.	246
Calorific value (not stated in table but would be about) B.Th.U.		19,165

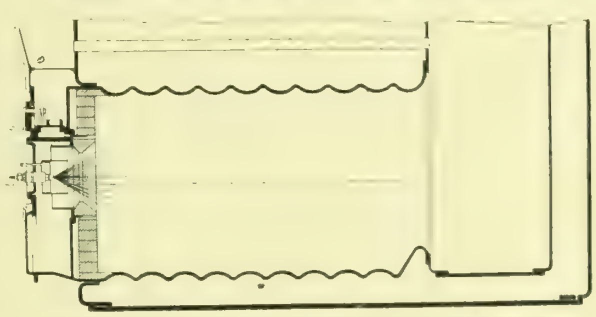
Actual practice shows that far less boiler trouble may be expected with oil fuel than with coal. Perhaps the most frequent source of leaky tubes in boilers is the constant necessity for cleaning fires when coal burning and currents of cool air pass to the back-ends. The only cleaning necessary with an oil system is the occasional removal of small quantities of carbon. This operation is performed through a small handhole door large enough to admit the slice. The furnaces are more evenly strained, especially with the systems where the whole of the furnace acts as a heating surface, and it is reasonable to suppose that the circulation is more efficient for the same reason.

The fact that the tubes are always more or less clean, and there is therefore no occasion to sweep them at sea, tends to give that part of the boiler a longer lease of life. As there are no sharp temperature differences at any part of the furnaces there is no pitting and corrosion. Collision chocks are eaten away by acids formed in damping ashes, as when cleaning coal fires.

No paper dealing with direct-pressure systems would be complete without a reference to the White mechanical oil system and the Wallsend patent liquid fuel burning system. These systems are similar in principle to Meyers, but vary in the details of construction. Drawings of these methods are here shown (Figs. 9 and 10). The Wallsend system is rather a confusing term, as the Wallsend Company have fitted various oil-fuel systems for the last 30 years. The system here referred to is their latest direct-pressure system. The incoming air is heated in a somewhat similar manner to the previous system. Fig. 10 shows the arrangement of furnace fronts for natural and forced draught. Fig. 4 shows a typical installation for a set of Cochran boilers. The Cochran boiler appears to be very efficient in connection with oil fuel. The firebars may be left in or removed. Where the bar fittings are left in position the surface of the bars should be covered with a brick lining with the exception of a space equal to two bricks, and suitable brickwork baffles arranged to retain



Wallsend-Howden oil-burning system for natural draught.



Wallsend-Howden oil burning system for forced draught.

FIG. 10.

the flame as far as possible without hindering the draught or choking combustion. The air space at the front bars enables additional air to be supplied from the ashpit, the quantity of which can be nicely regulated by the amount of opening of the ashpit damper.

When bar fittings are removed the bottom of the ashpit is lined with bricks and a rather larger area is available. In this case the burner is fitted to the ashpit door. The first method is perhaps preferable, as it may not be considered good practice to heat the furnace seam in the presence of the sediment which is always found at this point in any type of vertical boiler. Difficulty was experienced on the s.s. "Havre" in maintaining sufficient steam to run the auxiliaries in port on one burner—the construction of the

brickwork in use at the time allowing too much heat to pass to the funnel. The design was varied with the idea of retaining the flame in the furnace as much as possible, and the second trial proved very successful. On striking the brickwork the flame split into two parts, each of which completed a circle before leaving the furnace. Smoke and carbon deposits were entirely absent.

Fitted with the Howden system of forced draught and the Wallsend type of fuel burning, the s.s. "Wien," of the Austrian Lloyd's Steam Navigation Company, gave the following figures on a test of 47½ hours duration:—

Steam pressure	213lbs.
Indicated horse-power	9,667
Oil consumed per i.h.p. per hour for all purposes (including two refrigerating machines)	1·034lbs.
Oil consumed per hour per i.h.p. for propelling machinery	·907lb.

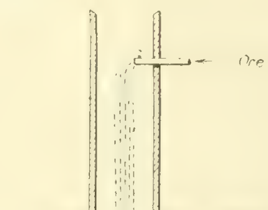
This test was recorded in 1911, since which time several minor improvements have been made in the design of burners and fronts.

The White mechanical oil system depends for its efficiency on the same principles as the foregoing. Fig. 9 illustrates the application for positive and for forced draught. The fronts are made in three types: Natural, positive, and forced draught. The latest improvements in the burner and its adjacent mountings deal in detail with the air supply in the immediate vicinity of the burner. By means of two sliding cones concentric with the burner the air supply about the burner can be varied to a nicety. This system has been introduced from the States, and has been adopted by several shipping firms in this country. The inside burner details are much the same as in the preceding systems. The oil is fed under pressure and rotated by its passage through tangential grooves cut in the button immediately in front of the orifice. The button is kept in position by a spring behind it.

The author has avoided more than a passing reference to the compressed-air system, having had very little experience in that direction, and because this system, like the steam system, is being taken out of modern vessels and direct-pressure systems installed.

STEEL CASTINGS DIRECT FROM IRON ORE.

To find a method by which Canadian iron ores could be economically handled, since they are not suitable for smelting in the ordinary blastfurnace without concentrating and briqueting, the Moffat-Irving Steel Works, Toronto, have



SECTIONAL VIEW OF ELECTRIC FURNACE.

during the past two years been experimenting with an electric furnace for the reduction of iron ores and their direct refining into steel. As a result of their investigations the company are, according to the "Canadian Engineer," now successfully manufacturing steel castings by the electrical process. The form of the furnace which is being used is based on the principle of the electric pig-iron furnaces of Sweden, and is shown diagrammatically in the accompanying cut. The crucible is built on a substantial base of concrete. Above this there are a few courses of hard burnt red brick, and finally the silica brick forming the main body of the crucible. The hearth is of rammed magnesite, furnishing a basic lining. The particles of ore are fed into the upper stack by a mechanical screw feed, and the necessary limestone is also fed in at the same level. The carbon, as finely ground coke, is injected similarly at the top of the crucible. The three electrodes, the current being three-phase, are projected into the crucible at an angle of about 60°, one only being shown in the illustration. The ore particles in falling come in contact with a strongly reducing hot atmosphere of carbon monoxide gas, being partly reduced thereby. Final reduction takes place in the crucible. A grade of steel from this furnace is being incorporated into castings which is claimed to be equal in every respect to the best crucible steel or to any other electrically produced steel. The average analysis of three heats is reported as carbon, 0·27 per cent.; manganese, 0·74 per cent.; silicon, 0·27 per cent.; sulphur, 0·010 per cent.; and phosphorus 0·031 per cent. Physical tests are said to be above the average and the appearance and quality of the castings to leave almost nothing to be desired. The company claims that the problem of handling Canadian ores has been solved by this process. It is, they state, the only furnace in existence that is commercially producing steel for castings direct from the ore.

CORRESPONDENCE.

Re Internal-combustion Locomotives.

To the Editor of "The Mechanical Engineer."

Sir,—

In your issue of January 9th you include a letter from a Mr. Durtnall, in which he states that an oil fuel can be obtained having a calorific value about 19,000 B.Th.U.'s per pound, and costing 25s. per ton delivered, which can be converted into a fixed gas suitable for use in "gas" engines. The ability to obtain and use a liquid fuel being admittedly the greatest advantage of an "oil" engine over a "gas" engine for marine purposes, it is obvious that such a combination as suggested for locomotives would remove the objections to the "gas" engine and open up a huge market for the manufacturers. It would therefore be of great interest if Mr. Durtnall would supply further details of such oil, and the plant suitable for gasifying it.—Yours respectfully,

MARINE ENGINEER.

Staffordshire Iron and Steel Institute.—At a meeting of this Institute held at Dudley on Saturday last Mr. H. J. Coe, M.Sc., read a paper on "Phosphorus in Iron." The author, in his summary of the paper, stated that the temperature of the commencement of solidification of iron saturated with carbon was lower by the addition of phosphorus, each 1 per cent. lowering the temperature by about 27° C. This effect reached a maximum with 6·7 per cent. phosphorus; further additions raised the temperature of the commencement of solidification. With the addition of phosphorus a new arrest of 950° C. appeared, the position of which was independent of the phosphorus content, though its intensity increased up to 6·7 per cent. and then decreased with further addition. The position of the pearlite point was not affected by the addition of phosphorus, though its intensity diminished and faded away altogether with 15 per cent. present. The solubility of iron for carbon was diminished by the addition of phosphorus.

Opening of New Premises of Institution of Mining and Metallurgy.—The Institution of Mining and Metallurgy has just acquired premises of its own, and what will in future be known as the House of the Institution was formally opened by the Lord Mayor of London, on the 13th inst. The premises are located at 1, Finsbury Circus, London, E.C., and the building is well adapted for the growing needs of the institution. Founded in 1892, the Institution has since rapidly developed. The membership, which in 1899, seven years after its formation, numbered 585, has increased to 2,372. The annual income is now £5,000, and capital funds have accumulated to an amount of £19,025. For a great many years the Institution has held its head-quarters at Salisbury House, and has held its meetings in the rooms of the Geological Society, in Burlington House. It has been evident, however, for some time past, that larger premises would have to be provided to meet the pressure thrown upon the existing accommodation by the growth of membership.

APPARATUS FOR REPAIRING THE TUBES AND FLUES OF SUPERHEATER LOCOMOTIVES.

THE following account, by Herr Uhlmann, of the Breslau Railway Directorate, giving details of the methods and apparatus employed on his system of roads for maintaining the tubes and flues of superheater locomotives, was published in the Organ fur die Fortschritte des Eisenbahnwesens and was reprinted in the Bulletin of the International Railway Congress Association for December, 1913.

In order to take out smoke tubes, the tube cutters designed by the author and shown in Figs. 1 and 2 are used. The tube is cut through at both ends immediately behind the flue sheets, the short ends left in the tube plates are removed and the tube is then taken out of the boiler through the front flue sheet. As the diameters differ, one tube cutter is used at the front flue sheet and another at the back flue sheet. The one used for the latter is shown in Fig. 1, and that for the former in Fig. 2; Fig. 3 shows how the tube cutters are worked. Both tube cutters are based on the same principle; two spindles, one of which is hollow, each have at their ends round discs of equal diameter. The hollow spindle is placed on the solid spindle in such a way that the corresponding faces of the disc are against each other. The face of the disc on the solid spindle has a scroll on it, while the face of the disc on the hollow spindle has a number of slots cut in it radially at equidistant intervals. These slots take cutters made of self-hardening steel, which project beyond the slots and are toothed so as to engage with the scroll. If one spindle be rotated more rapidly than the other, the cutters will advance or retreat radially, the movement of the cutters being equal to the pitch of the scroll, when one or the other of the spindles has made one complete revolution more than the other.

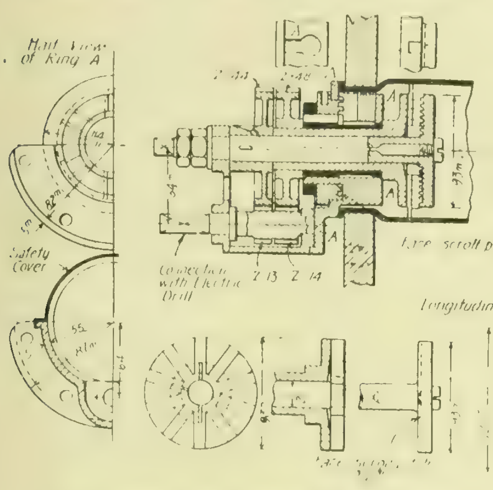


FIG. 1. DEVICE FOR CUTTING FLUES AT FIREBOX END.

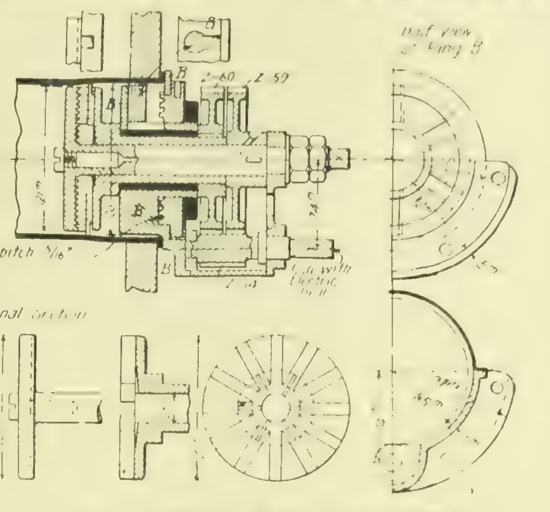


FIG. 2. DEVICE FOR CUTTING FLUES AT SMOKE-BOX END.

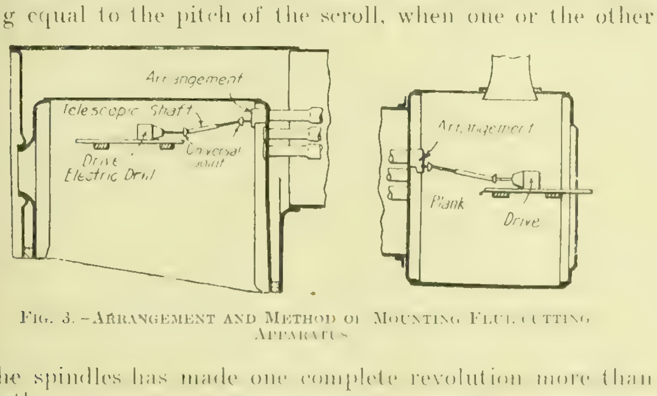


FIG. 3.—ARRANGEMENT AND METHOD OF MOUNTING FLUE-CUTTING APPARATUS.

The advance or retreat is effected by a differential drive, so arranged that the cutters advance at most 0·083 mm. (0·00327in.) for each revolution of the spindle. The spur wheel on the solid spindle is secured to it by means of a key in such a way that it can readily be released; it being possible to make the cutters advance or retreat quickly. The tube cutter is secured to the flue sheet by means of six jaws which, like the cutters, are operated by a scroll. The tool may be worked by an electric or a pneumatic drill which engages with a telescopic shaft with universal joints fixed to the square end of the small driving wheel as shown in Fig. 3. The advantage of using such a shaft is that the drill can remain fixed in one position until all the smoke tubes have been cut out. With these tube cutters, about seven minutes are required for cutting out a tube at the front flue sheet, but about nine minutes for one at the back flue sheet. Before these tube cutters were used, it was the practice to use the oxy-hydrogen flame for cutting the tube. This process cost a little less for wages, but in consequence of the consumption of oxygen and hydrogen it costs on the whole more by an amount which varied; moreover, the men do not like this process, as they often burn their clothes.

In welding on safe ends, which is best done at the front end, the tubes are turned down on a lathe specially arranged for this purpose, so that the end where the weld is to be conical, and the end of the sleeve is countersunk to correspond as at *b* Fig. 4. A special welding forge is used for the welding operation. Recently successful experiments have been made in the use of acetylene and oxygen for welding. In this case, the ends which are to be welded are given a slight taper from the outside, so that a groove is formed between them, which is filled with melted Swedish charcoal iron and finished off with the hammer before it becomes cold. Tensile tests made with tubes which had been welded in this way have shown favourable results. The bars broke near the weld and showed an ultimate tensile strength of 49,780lbs. to 51,200lbs. per square inch, while that of the tubes welded in the welding furnace mentioned above, varied between 42,670lbs. and 53,335lbs. per square inch, according as fracture occurred at the weld or near it. Welding with acetylene and oxygen is somewhat cheaper, and this process can be recommended.

The tubes are contracted at the firebox ends; this is done by swaging under a steam hammer. Before the tubes are put into the boiler again, they are taken to the lathe mentioned above and the places where they are rolled in are turned smooth and provided with three small grooves. In addition those holes in the firebox flue sheet, which are no longer truly round, must be bored true by means of the tool shown in Fig. 5, care being taken to reduce the interspaces as little as possible. This tool consists of a casing, which is a steel casting, with two spindles and a spider for securing it to the flue sheet. The drill spindle has at the back a sleeve with a square thread and nut, which does not revolve with the spindle but acts only as a feed. The feed is by hand, but it can also be worked automatically if desired. An electric or pneumatic drill supplies the drive. If the holes in the flue sheets have become too large, flanged copper bushings, 3 to 4 mm. thick, are driven in from the water side and expanded a little on the fire side in the countersink around the edge of the hole as at *c* in Fig. 4. The end of the bushing must be flush with the surface on the firebox side, and the flange on the water side must be well against the sheet; if necessary the two surfaces of the sheet are trued by means of the tool just described, a suitable cutter being inserted. The bushings

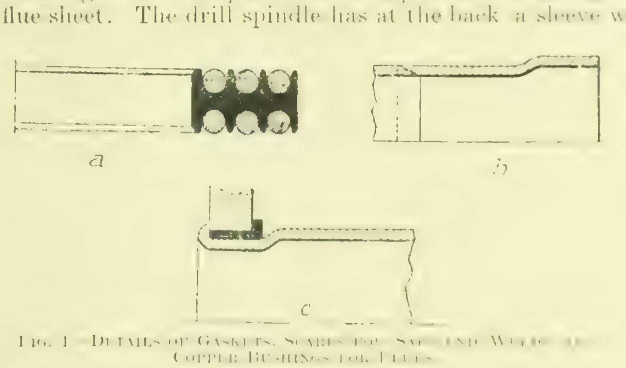


FIG. 4.—DETAILS OF GASKETS, SCARFS FOR SAFE END WELDS AND COPPER BUSHINGS FOR FLUES.

are stamped out of copper sheet of suitable thickness and require but little machining. They have given good results for years and remain tight. They protect the interspaces between the tube holes well, and also help to prevent the tube holes from becoming deformed and out of true.

For expanding the tube in the flue sheets, the roller tube expanders, shown in Figs. 6 and 7, are used, the latter being

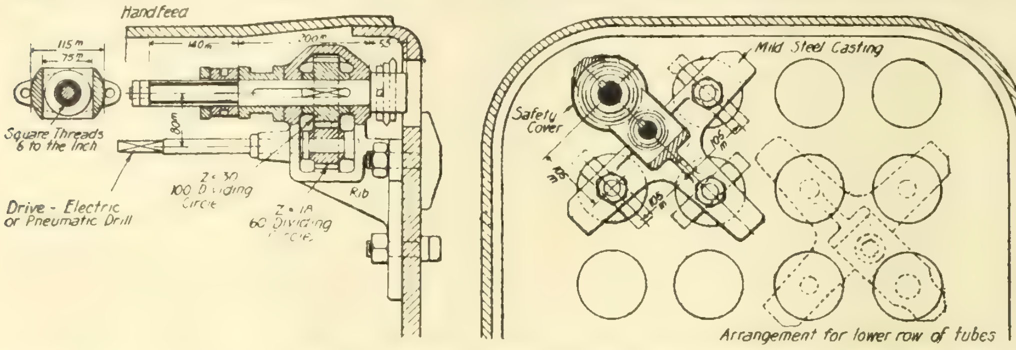


FIG. 5.—DEVICE FOR TRUING HOLES IN FLUE SHEETS.

used for producing the shoulder at the back tube sheet. In the case of superheater tubes, care must be taken, before fixing them to the steam header, that the surfaces are clean and smooth. Any rough or uneven surfaces must be milled true first, as it is otherwise impossible to obtain tight joints even if the best packing rings are used.

In order to mill these surfaces, the tool shown in Fig. 8, also designed by the author, is used. With this it is possible

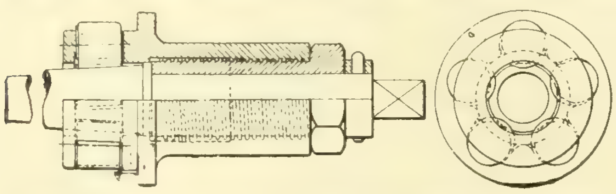


FIG. 6.—ROLLER EXPANDER FOR USE AT SMOKEBOX FLUE SHEET.

to mill the two surfaces simultaneously, but it is also possible to do the surfaces separately, as each of the two spindles has its independent adjustment. The unit to be machined is supported on a plate which can be moved by a screw and hand wheel, so that both cutters can be put in or out of

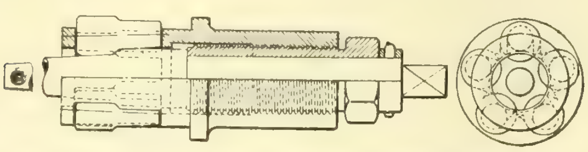


FIG. 7.—ROLLER EXPANDER FOR USE AT FIREBOX FLUE SHEET.

operation simultaneously. The drive for this device is the same as with the other tools.

As regards packing rings, the best results were obtained with rings made of soft ingot iron, with circular grooves filled with asbestos as shown at *a*, Fig. 4. When used over again, the grooves must be filled with fresh asbestos.

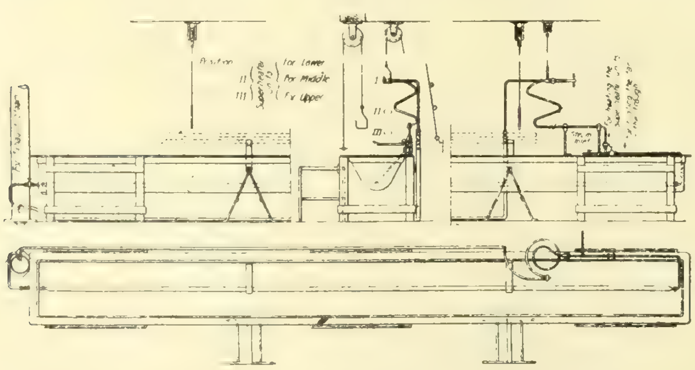


FIG. 9.—ARRANGEMENT OF TROUGH FOR TARRING SUPERHEATER UNITS.

In order to protect the superheater tubes against rusting, they are carefully cleaned and tarred before they are put in again. They are tarred in an iron trough (Fig. 9), which is about half-filled with tar and is of such length that it can hold a superheater unit. A longitudinal steam pipe in the trough heats the tar. The superheater, when introduced into the tar, is supported on two iron hooks fastened to ropes which run over fixed pulleys. After the tarring the unit is placed on two projecting holders, and in order to accelerate the drying they are connected with hours until a suitable stopping place could be reached; and the steam pipe; the end of the unit in the meantime being tarred by hand. The steam pipe ends in a flexible copper pipe coil in order that the union can, to suit the length of the end of the superheater unit, be readily brought into positions I., II., and III. Experience has shown that the superheater units become strongly corroded inside in course of time, the corrosion varying with the amount the steam is superheated; the corrosion is consequently greatest at the exit ends of the units. On this account the units require careful examination, particularly at the exit end, before they are put in again; it is usual in our practice to cut open several tubes longitudinally, in order to see how far the corrosion has gone. The water-pressure test does not give a reliable indication, as owing to the cellular shape of the corrosions, the tube can still be tight although considerably corroded. According to

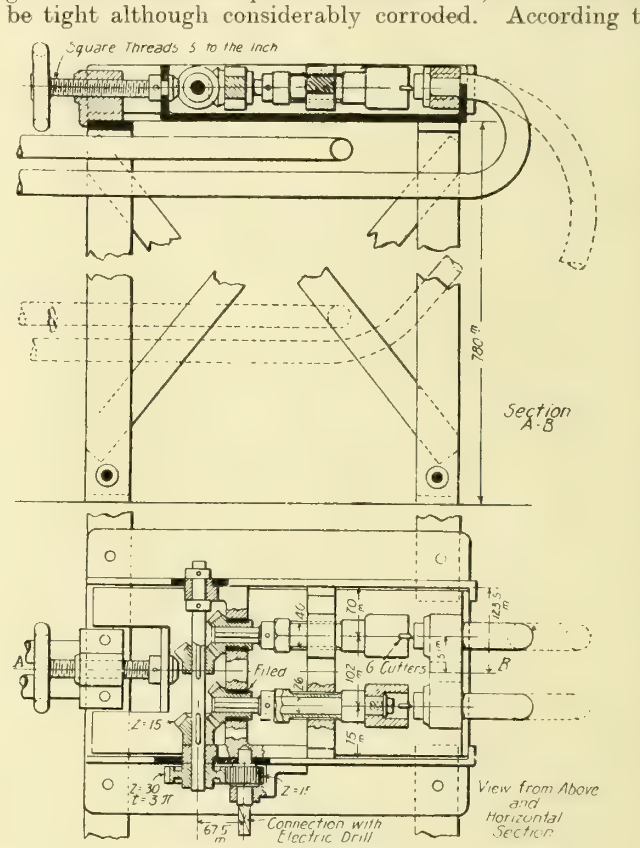


FIG. 8.—APPARATUS FOR MILLING CONTACT SURFACES OF SUPERHEATER UNITS

the author's experience, it is not necessary to examine the superheater tubes until they have been in use over three years. In order to know the age of the tubes, the date (month and year) is punched on the block securing the unit, at renewals.

Staveley Boiler Explosion.—The formal investigation ordered by the Board of Trade to be held in this matter is fixed for hearing in the Committee Room, Stephenson Memorial Hall, Chesterfield, on Wednesday, the 28th inst., at 11 a.m.

The Junior Institution of Engineers: North-Western Section.—The first discussion meeting of the newly-formed North Western Section of the Junior Institution of Engineers was held in Manchester on Friday evening, the 19th ult., Mr. C. H. Prichard (Chairman of the Section) in the chair. The discussion, dealing with the education of the engineer, was opened by Mr. Maurice Hird, and was continued by a number of other speakers.

THE MEASUREMENT OF STRESSES IN MATERIALS AND STRUCTURES.*

BY PROF. E. G. COKER, M.A., D.SC.

THE study of the behaviour of materials under load has always exercised the greatest interest, whether regarded as a field of mathematical and philosophical enquiry, or as an experimental science; and the labours of a vast number of investigators have slowly built up a science of the strength of materials which rests upon an assured basis. Modern needs, and the ever-widening fields of enquiry caused by the quickening

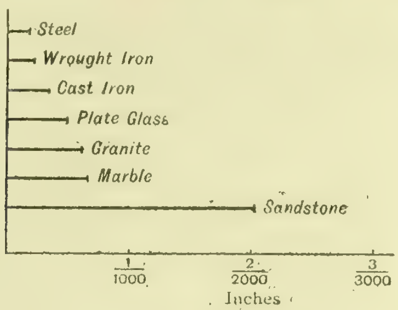


FIG. 1.

influences of discoveries in other branches of science, are continually leading to new and more exacting demands on metals and other like bodies used for constructive purposes, and it is therefore not an unprofitable task to attempt a review of a part of the science of the strength of materials which is more directly connected with experimental enquiry, since this aspect of the subject has a most important bearing on the design and construction of all kinds of fixed and moving structures subjected to static and dynamic loads. Theoretical investigations have in a large number of cases given exact solutions of the stress distributions in elastic bodies of definite geometrical shapes, which latter in some instances approximate very closely to the forms of actual structures; but in the great majority of instances this is not the case, since the forms and dispositions of machines and structures are decided by a number of circumstances which lead to complicated shapes not amenable to calculation, and not always the most perfect owing to the practical difficulties of construction. For example, steam boilers more often than not are cylindrical vessels with flat ends, and the reasons for giving them this form are well known and practically justifiable, although when considered merely as vessels for resisting internal pressure they are not the most perfect which could be devised, while the effects of riveted joints and other discontinuities usually increase the stress intensities in a prejudicial manner difficult, if not impossible, to determine by calculation.

In this, and other like cases of mechanical construction of great commercial importance, every part of the structure has in course of time been subjected to the most careful scrutiny

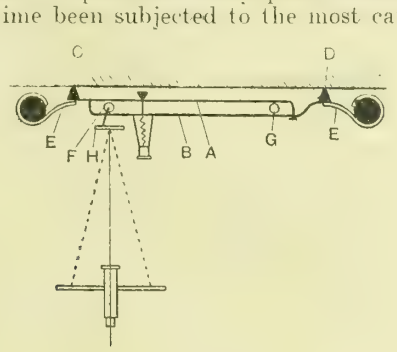


FIG. 3.

as regards stress distribution in the material; but even with all our accumulated experience of the construction of boilers it can hardly be said that our knowledge of the stresses in them is exhaustive, and the same may be said probably of almost any other type of structure or machine in present use. In new forms of construction, like aeroplanes, where prolonged experience is lacking, the frequent failures due to breakage of an essential part of the structure are undoubted evidence of our want of exact knowledge of the stress in the material, and its proper distribution to resist the loads coming upon it. Very great difficulties confront the investigator desirous of ascertaining the stress distribution in any given body which is subjected to an arbitrary loading system, and this will appear from the consideration of various methods which have proved of value.

The guiding principle of most of the experimental work which has been accomplished in this field of enquiry is the well-known Hooke's law, which expresses a linear relation between stress and strain. This law is found to be approximately true for the principal materials used for constructive purposes, although the deviations therefrom are not always unimportant. If we take the case of a simple tension or compression member, we find that the strain or extension per unit of length is, in general, simply proportional to the load, and although its amount differs widely with the kind of material used, yet the linear relation is sufficiently exact to enable the stress to be inferred from the strain measurements. The amount of alteration in the length of a specimen is, in general, so small, however, that apparatus of great precision and delicacy is required for measurement, or else the length taken must be so great that the total change is considerable. This may be readily appreciated by a comparison of the changes produced in a length of 1in. of some well-known materials when subjected to a load of, say, 5,000lbs. per square inch in either tension or compression, according to the material employed. The changes of length are shown on diagram

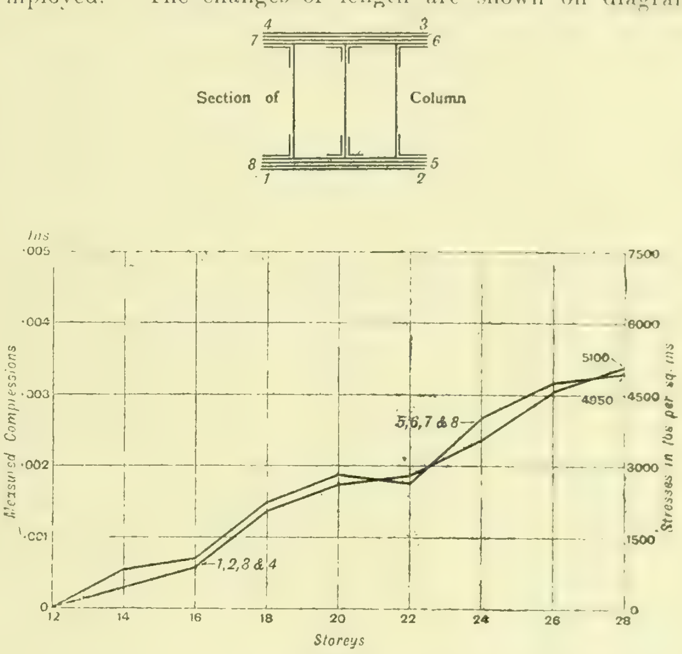


FIG. 2.

(Fig. 1), and we observe that steel shows a change of about $\frac{1}{6000}$ of an inch, and wrought iron slightly more, while cast iron gives double this amount, and is a near neighbour of plate-glass, which it also resembles in some other ways. Granites differ considerably according to their origin and structure, but we may expect to find an alteration of about one-thousandth part of their length under the specified loading, while in sandstone the strain is considerably greater, a fair value being $\frac{1}{500}$ of its length. If, therefore, the stress distribution in a metal is to be inferred by measurements of strain, it is apparent that even in the simplest cases, where only tension or compression stress occurs, we require to know the small changes of length with very great accuracy, since an error of a few millionths of an inch in the measurement of the change of our unit of length is not an inconsiderable part of the total strain, while if the stress varies greatly it is necessary to make the measurements upon a very small length to ensure even approximate accuracy.

A great many measurements have been made of the measuring strains in tension and compression members, beams, and columns for cases of loading in which the strains over considerable lengths may be taken as uniform, and other cases of uniform strains, producing angular distortion and change of volume, have often been the subject of experimental investigation. All these, however, constitute only a small portion of the problems which are of practical importance, since, in general, the strains produced by loading a structure or

* Cantor lectures delivered before the Royal Society of Arts, December, 1913, and reproduced from the Journal of the Society.

machine are complex functions of the simple ones described above, and vary greatly in magnitude as we pass from one point to any neighbouring point in the structure, so that the average values taken over a length, area, or volume do not usually represent the actual conditions correctly. The applications of strain measurements to actual structures are therefore somewhat limited, and in any case demand very great care and accuracy in the measurement of very small changes in lengths and angles.

A simple example of measurements upon an actual structure is furnished by some observations which were made upon the steel columns of the Bankers Trust Company's building during the progress of the erection. This is a building of 38 storeys supported on columns of the section shown in Fig. 2, having a cross-sectional area of 275 sq. in. and a modulus of direct elasticity of 3×10^7. Distances of 20in. were marked off on the plates, and small countersunk holes were drilled in the metal before any load was applied. Measurements of the alterations in length were taken as the building progressed by aid of a simple form of screw micrometer capable of detecting a change of length of ·0002in., corresponding to a change of stress in the material of 300lbs. per square inch. Some of the observations are shown in Fig. 2, during the interval in which a load of 16 additional floors was added, and the places of measurement are indicated by numerals. The changes in length show a gradual increase as the work of building progresses, but are somewhat uneven, but this irregularity is no doubt due to the fact that the protective masonry screen is supported by the framework, and its addition may not be so uniform as in an ordinary building in which the masonry is necessarily built up from the foundations. Some differences of stress are shown at different parts of the section, but except in one or two instances they are not large, and the mean values may therefore be taken with considerable accuracy. It is readily verified, for example, that the addition of these 16 storeys imposes an extra stress of 5,000lbs. per square inch, or a total of 1,375,000lbs. on the column.

Another case constantly occurring in practice is due to bending moment applied to rolled steel beams of I section, and this type of stress distribution may be conveniently illustrated by an experiment taken from my laboratory notes, in which the changes in length of the flanges and web of an I beam were measured by means of a special form of extensometer using loads which gave a uniform bending moment over the measured length. Since the strains in this example are uniform in the direction of the length of the beam, it is permissible to take average measurements over a considerable length, and this is accomplished by means of a roller extensometer which can be clamped to the flanges or to the web of the beams. The essential features of the instrument are very simple, and consist of a pair of steel rods, A B, Fig. 3, provided with knife edges C D, pressed against the surface by suitable clamps E, and preserved parallel to one another and to the beam surface by a pair of friction rollers F and G, one of which carries a reflecting mirror H. A longitudinal strain in the beam causes a proportional change in the distance between the knife edges C D, and in consequence the rollers pressed against the rods by a spring are rotated through a small angle, and this latter is measured by a reading telescope and scale placed at a considerable distance away. The changes of length per inch are measured in this way, and the values so obtained in this case are shown in Table I. and Fig. 4, the unit of measurement being a millionth of an inch. The stresses produced are readily obtained by multiplying by the known ratio E of stress to strain, and for this steel the ratio is about $3{\cdot}1 \times 10^7$ in pound and inch units. If, then, we multiply by this amount we finally obtain the stress distribution across the section of the beam as shown by Fig. 4, in which the strains are plotted to scale, and the stresses are determined by multiplying by the modulus E. Our results show us that the stress across the section is a uniformly varying one with a zero value nearly at the centre of the depth, as may be verified by calculation for this simple instance.

TABLE I.

Bending moment. Inch lbs.	Strain in Millionths of an Inch per Inch in		Web.		
	Top flange	Bottom flange.	$1\frac{1}{2}$in. above centre.	At centre.	$1\frac{1}{2}$in. below centre.
10,500	−41	−42	−21	0	−21
21,000	−82	−83	−42	−1·0	−40
31,500	−124	−126	−63	−1·5	−61
42,000	−166	−168	−85	−2·5	−81

A somewhat more complex case of practical importance is presented by beams of concrete reinforced by steel on the tension side, which are now so largely used in the construction of buildings. Measurements of strain are not an infallible guide to the stress distribution in such cases, because concrete has a comparatively feeble power of resisting tension, and due account must be taken of this in interpreting the results of strain measurements. Another example taken from my laboratory notebook will make this clear. A rectangular beam of cement 4·05in. wide and 5·9in. deep was reinforced by three steel rods $\frac{3}{8}$in. diam. at a distance of $\frac{3}{4}$in. from the under side as the section shows. The beam was loaded by a uniform bending moment over its central portion, and strain measurements were taken in the direction of the length by a roller extensometer. The behaviour of the beam was not that of a perfectly elastic body, and the strains for equal increments of load were not always quite equal, as the following Table II. shows, in which the applied load consisted of two equal forces each of 1,500lbs. applied at distances apart of 18in., the beam being supported on centres 48in. apart, so that the bending moment over the central section was $1{,}500 \times 15 = 22{,}500$in.-lbs.

The measuring instrument was calibrated on a Whitworth measuring instrument at the conclusion of these experiments, and it was found that a unit of the table represented $\frac{1}{490000}$in. on a length of 8in. The mean values of the strains observed in the cement are plotted in Fig. 5, and we observe that the strains are fairly linear, and the neutral axis is above the centre of the beam. The stress distribution cannot therefore be proportional to the strains over the whole section, since they do not balance if such is the case, even neglecting the effect of the reinforcement. It is usual, in fact, to neglect altogether the tensile resistance of the concrete in a beam and assume that the reinforcement takes all the tension, but in this example the cement probably resists tension to some extent, and we can form an idea of the part each material plays in resisting the external forces. The cement at the time of the test had a modulus of elasticity in direct compression

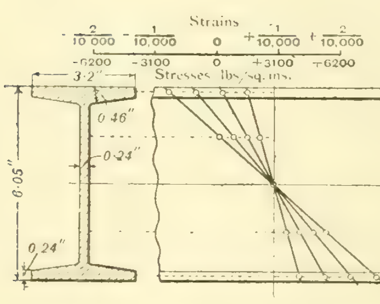


FIG. 4.

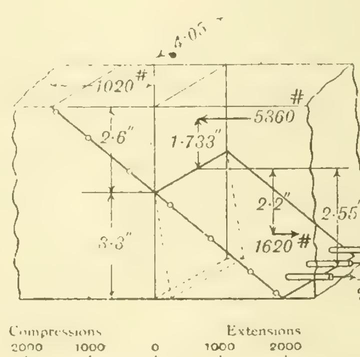


FIG. 5.

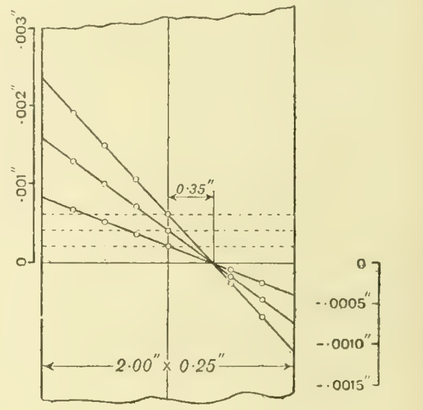


FIG. 6.

of approximately $2·56 \times 10^6$, while that of the steel was nearly 3×10^7.

TABLE II.—*Strains Measured at given Distances from the Top of the Beam in Inches of*

	0·1	1in.	2in.	2·6in.	3in.	4in.	5in.	5·8in.
First loading ..	1510	1005	400	—	222	888	1115	1865
Second „ ..	1535	1015	410	—	218	856	1120	1884
Third „ ..	1540	1010	400	5	217	856	1142	1885
Fourth „ ..	1550	1005	400	·15	209		1420	
Mean value ..	−1534	−1009	−403	−5	−217	867	1432	1878

These values enable us to calculate that the maximum compression stress in the cement is 1,020lbs., and the total push it exerts above the neutral axis is 5,360lbs. Again, on the assumption that the strain in the steel differs little from that of the cement at the same depth, we find that the mean tension stress in the steel is 11,000lbs. per square inch and

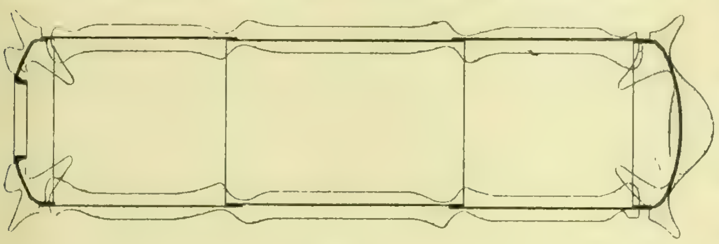


FIG. 7.

the total pull it exerts is 3,740lbs. As the total tension equals the total compression the remaining 1,620lbs. must be taken by the cement. The strain measurements also show that whatever be the proportion of load borne by the two materials the stresses are distributed linearly, so that we may readily calculate the contribution of each to balance the external bending moment, and we find under the assumption stated that the concrete takes 9,290in.-lbs. in compression and 3,560in.-lbs. in tension, while the steel takes 9,540in.-lbs., leaving a balance of 109in.-lbs. not accounted for. The proportion of tension to stress taken by the cement is indicated to scale by the dotted lines of Fig. 5. If the steel is strained more than the corresponding surface layer of the cement it will take a larger proportion of the stress, and in practice it is generally assumed to take all the load not taken by the compression stress.

Bending moments.	Inch lbs.	
Cement in compression	$5{,}360 \cdot \frac{2}{3} \cdot 2·6$	9,290
Cement in tension	$1{,}620 \cdot \frac{2}{3} \cdot 3·3$	3,564
Steel in tension	$3{,}740 \cdot (3·3 + 0·75)$	9,537
	Total	22,391
	Bending moment applied	22,500
Difference		109

A further example of stress measurement, which is described because of its application to a more complex case, occurs in an eccentrically loaded tension member. Strains along lines parallel to the length are readily measured in such a case, and afford a useful laboratory experiment. Fig. 6 shows the results of strain measurements obtained by one of my students for the case of a bar 2in. by ¼in. in cross section and loaded 1in. out of line in a testing machine. We observe that the maximum strain is reached on the side nearest the line of action of the load, and gradually diminishes to zero at a distance of 0·35in. from the centre upon the other side, and ultimately reaches a negative maximum at the greatest distance from the line of action of the applied force. The mean strain in the bar for a central load is also shown by dotted lines, and it may be readily verified from the figure, and also from Table III., that the mean strain is substantially one half the sum of the two end strains, a result which is made use of in a stress determination described below. Measurements of this type have been frequently applied to determine the stresses experienced in bridges, ships, boilers, and the like, and to avoid the possibility of error, which may occur owing to the tacit assumption that the stress and strain are uniform over a given length, we find that every effort is made to attain the ideal condition of measurement of the strain over the shortest possible length, in fact, to obtain the strain at a point.

TABLE III.—*Steel Bar 2in. by ¼in. Loaded along one side. Length under Measurement 8in.*

Total load.	Extension. Inner edge.	Outer edge.	Mean.	Central load.
Lbs.	Inches.	Inches.	Inches.	Inches.
400	.0008	.00038	.00021	.00022
800	.00159	.00075	.00042	.00043
1,200	.0024	—.00112	.00064	.00065

Many noteworthy researches on the strains in complex metal structures have been made, and one or two examples may be briefly described, which, in addition to their intrinsic interest, also serve to illustrate some of the difficulties to be overcome. A recent experimental determination, by Messrs. Barraclough, Gibson, and others, of the strains in the steam drum of a Babcock & Wilcox boiler may be taken as a typical example of a very difficult problem of strain measurement. The shell of such a boiler is not only changed in length owing to the applied internal pressure, but the initial curvature of the plates is also altered in such a manner as to cause severe stresses due to bending. We have therefore two distinct strain systems of importance which are convenient to measure separately and to combine later for determining the stress. A principal object of these experiments was to determine the influence of the riveted joints upon the stress distribution, and hence longitudinal and transverse sections of the boiler were explored by external surface measurements of two kinds. The first was directed to the measurement of the changes of length in the chosen directions, and for this work very short extensometers of the well-known Marten's Mirror type were employed. The second series of measurements to ascertain the changes in the curvature of the plates were carried out by mirrors securely fastened to the shell of the boiler at short intervals, and their angular changes in position under the load were observed by reading-telescopes. The effects due to bending were determined on the assumption that stress is proportional to change of curvature, and the direct stresses were inferred from the linear relation of strain to stress. The algebraic sum of the two stresses at a point was then taken as the total stress at the external surface. At the interior surface, where direct measurement was impossible, it was assumed that the variation of stress distribution was linear across the thickness of the shell, and of the same type as that already described with reference to an eccentrically loaded tension member. The relation already referred to between the mean strain in an eccentrically loaded tension member and the strain at each side of the bar was assumed to hold for the shell plate of the boiler, and the stress at any point of the interior surface was

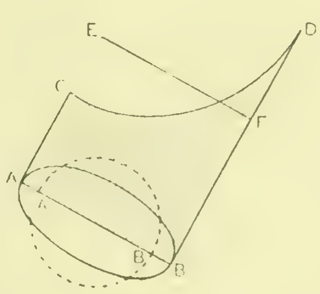


FIG. 8.

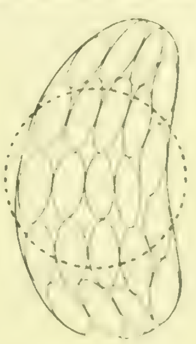


FIG. 9.

inferred from the strain so deduced. The stress distribution throughout the boiler shell was mapped by these means, and the results obtained are shown in a graphical manner by the longitudinal section (Fig. 7), in which the surface stresses are plotted perpendicularly to the plate, tension being denoted by dotted, and compression by firm, lines. The stress in the domed end is conjectural, but in all other cases the diagram gives a record of the actual strain measurements.

In these interesting results we can at once see that fair uniformity of stress in the material is only attained at considerable distances from all joints and changes of curvature.

and there are rapid changes of stress intensity due to both causes wherever they occur, usually resulting in great increase of stress. Stress intensities of two or three times the mean value are shown to occur near joints and changes of curvature, and the weakness of single lap joints and sharp bends is amply demonstrated by reference to direct experiment and to many cases of boiler failures. It would be most interesting to consider at length other conclusions deduced by the authors, such as the connection between pitting of the plates and high stress intensity, did it not draw us too far from the subject in hand. It is important to note that the principal strains in a boiler shell are in the longitudinal and transverse directions, and that the principal stresses are simple functions of both.

As the effects of stresses at right angles in a plane will come up again when other methods of stress measurement are discussed, it will be convenient to discuss this typical case here. It can be shown that every possible state of stress which can arise at a point in a plane lamina may be represented by two stresses, p and q, at right angles, and the effect of such a stress system of this type is to cause strain, which deforms circles into ellipses having principal axes in the directions of the stresses p and q. The stress distribution at a point in a plane may be inferred if the directions of the greatest and least strain, as well as their magnitudes, are determined. If e_1 and e_2 are the strains in the directions of the principal stresses p and q respectively, there is a simple relation between them expressed by the equations I. and II.:—

$$p = E(e_1 - \sigma e_2) \text{ (I.)} \qquad q = E(e_2 - \sigma e_1) \text{ (II.)},$$

where E and σ are constants of which the latter has a numerical value for steel in the neighbourhood of $\frac{1}{4}$. The

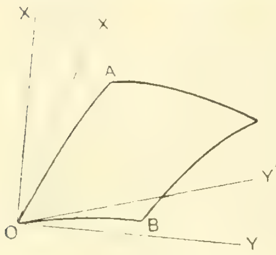


FIG. 10.

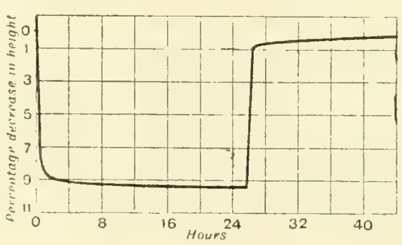


FIG. 11.

values of the principal stresses in a plane depend, therefore, upon the two principal strains. In the above determinations the fractional part of the second strain is not considered of sufficient importance to be taken into account, but its effect is, in general, somewhat to decrease the values of the principal stresses. It will be apparent that the inherent difficulties of strain measurements are very considerable, and the effect of the length measured is of particular importance in many cases.

This influence may be readily examined if we take a circle as our type of unstrained figure. The strain per inch of length of a piece of steel subjected to a tension of compression stress of 5,000lbs. per square inch is less than two ten-thousandths of an inch, and to obtain this strain to an accuracy of 5 per cent. for a circle of $\frac{1}{10}$in. diam. requires measurements to an accuracy of one hundred-thousandth of an inch. The strain so obtained is an average for the length considered, and it may vary in value at each point. If, for example, the strain experienced at each point of the diameter A B of an unstrained circle (Fig. 8) is plotted to a sufficiently large scale upon the altered length A^1 B^1 it may vary in some such way as shown by the curve C D, and the measured mean value E F will therefore only be true for one point of the diameter, not necessarily the centre of the circle, or even capable of exact reference. Such cases invariably occur at or near discontinuities, and in a simple case like that of a small hole in a member the strain at the edge of the boundary may be several times greater than it is at a distance away equal to the diameter of the hole. Another possible source of error is due to the tacit assumption that a finite circle deforms into a true ellipse. It may, however, take a somewhat different form, in which, although every circular element becomes an ellipse, the whole area is not of this type. We may have, in fact, a small finite circle, like that shown dotted in Fig. 9, within which are inscribed an indefinitely large number of smaller circles, each one of which becomes an ellipse due to the strain, yet the boundary suffers such a distortion that the magnitudes and directions of the principal strains cannot be determined from the reference figure.

Similar difficulties may be met with in the determination of shear strains, which produce angular distortions of the type represented in Fig. 10, in which perpendicular axes O X and O Y are deformed by a uniform shear into the positions O X^1 and O Y^1. If, however, variations of shear stress occur along the axis these lines become curves O A, O B, and the change of angle at O, which measured the strain, is difficult to determine. The smallness of the strains is, however, the principal experimental difficulty, and in most cases this has proved an insuperable obstacle to the direct determination of strain distribution in metals. For many practical purposes, however, valuable information may be obtained from experiments on models constructed of materials capable of suffering considerable deformation without injury to their elastic properties, and in this manner many important engineering problems have been successfully dealt with. In this connection it is important to point out that the stress distributions, in different elastic bodies of similar shape, and with the loads upon them correctly proportioned, give similar stress distributions provided their elastic limits are not exceeded. Unfortunately, materials, like india-rubber, which are capable of large deformations are not perfectly elastic, and there is usually a considerable lag between the stress and the strain, which must be taken into account. This defect of elasticity may be illustrated by an experiment in which a block of india-rubber was subjected to a compression load and its diminution in height noted at considerable intervals. A compression strain of about 8 per cent. at the time of loading gradually increased with time, and attained a steady value of approximately 9·3 per cent. at the end of 26 hours (Fig. 11). The load was then removed, giving a nearly immediate recovery to within about 1 per cent. of the original height, followed by a slow recovery, which at the end of another 14 hours brought the block to within $\frac{1}{2}$ per cent. of its original length. In experiments on rubber, therefore, the loads are generally applied for some time before measurements are taken, and ample time is given to allow a model to recover its shape after the removal of the load.

(To be continued.)

A TALL STEEL CHIMNEY.

THE 400ft. steel chimney of the United Verde Copper Company, Jerome, Ariz., is believed to be the tallest steel stack in the world. The chimney, which was described in a recent issue of "Engineering News," is 30ft. diam. inside the brick lining, 30ft. 9½in. inside of the steel shell, and 400ft. 1in. from top of foundation to top of steel. The diameter and height of the chimney were determined by the draught calculations; the diameter and height of bell were made one-eighth of the height of the chimney, or 50ft. The brick lining was supported on the legs of circular angles riveted to the inside of shell and spaced 15ft. apart. By this method, the bearing capacity of the brick is not exceeded and any section can be replaced without affecting the others. The weight of brick is carried directly down the shell and was added in when computing the maximum stresses on the compression side, but was neglected on the tension side as it was assumed that the maximum wind might occur before the chimney was lined. The wind load was assumed to be 50lbs. per square foot, or 25lbs. per square foot on the projected diameter, equal to 770lbs. per foot of height. The dead load was taken as the actual weight of steel, plus the weight of brick lining assumed at 112lbs. per cubic foot. The following unit stresses were used: Tension, 16,000lbs. per square inch, on net section; compression, 10,000lbs. per square inch, on gross section; shop rivets, 10,000lbs. per square inch for shear and 20,000lbs. for compression; field rivet values 80 per cent. of shop. The section modulus of any section was computed by multiplying the area of the inside of shell by the thickness. The foundation is made of concrete reinforced, and is octagonal with a short diameter of 70ft. and a depth of 10ft.

INDUSTRIAL AND TRADE NOTES.

United States Coal Production in 1913. A coal production between 565,000,000 and 575,000,000 net tons of coal in the United States in 1913 is the official estimate of Edward W. Parker, coal statistician of the United States Geological Survey. This is an increase over the record-breaking production of 1912 of 30,000,000 to 40,000,000 tons. Of this increase about 4,500,000 tons was in the production of anthracite.

Enquiry into Trade Conditions in Siberia and China.—The Advisory Committee to the Board of Trade on Commercial Intelligence, at a meeting in London on the 13th inst., decided that special commercial missions should be dispatched at an early date to investigate the conditions and prospects of British trade in Siberia and China. Among other matters considered were the collection of samples of foreign goods competing with United Kingdom manufacturers in the self-governing Dominions, and questions relating to the work of the Commercial Intelligence Branch of the Board of Trade.

Geared Turbines for American Warships.—A contract has, we learn, recently been placed for the fitting of Westinghouse gears in the U.S.A. battleships "Pennsylvania" and No. 39. The gears are to be interposed between the cruising turbines, the main turbines being direct connected. There are to be two reduction gears on each ship, those in the "Pennsylvania" being 1,500 h.p. each and in No. 39 of 2,000 h.p. each. It is understood that a preference of 30 per cent. in price was accorded the Westinghouse gears on account of the floating frame and dynamometer features. The Westinghouse Machine Company have also received a contract for a 4,000 h.p. gear for the "Melville."

Russian Petroleum Production in 1913.—The "Borsen Zeitung" states that, in contrast to the development of Russian coal production, which shows a continual improvement, the Russian petroleum production has been very poor. During the year 1913 the production only amounted to 559 million pouds, which is six million pouds less than the previous year (1,000,000 pouds = 16,121 tons). The Baku production, which amounted to 431 million pouds, would have been much greater but for a lengthy strike which occurred in the works. It is estimated, also, that an improvement in the industry will take place this year, and a total production of 583 million pouds is anticipated, which would represent an increase of 24 million pouds over last year.

Boilermakers' Society and Shipwrights' Association. — Negotiations between the Boilermakers' Society and the Shipwrights' Association, with a view to a closer working arrangement between the two unions, were carried a stage further, when representatives of each society recently met at Newcastle to consider a draft scheme framed by a sub-committee. It has been realised that complete amalgamation between the unions could only be attained by patient endeavour in view of the diversity of rules, contributions, and benefits. Draft proposals for securing the object in view were presented by a sub-committee, and accepted by the general committee. These will be submitted to the members of both societies in due course, and a vote of the branches will be taken for their confirmation or otherwise. The combination, if endorsed by the members, will be an important factor in the future regulation of hours and wages in the shipbuilding industry. The membership of the Boilermakers' Society is 66,000, and that of the Shipwrights' Association about 28,000.

New Zealand Hydro-Electric Power Plant.—The first installation of 6,000 h.p. of the Lake Coleridge electrical supply scheme is expected to be put into operation by May next. The plant is designed for a total capacity of 9,000 kw., and the power generated will serve the needs of the Christchurch City Council, and some 15 other local bodies, for the electrification of the Christchurch-Lyttelton suburban railway, and for the requirements of works. The natural features of Lake Coleridge and the adjacent rivers will allow of a very large extension of the supply up to 58,000 h.p. The contract entered into by the Christchurch City Council will enable that body to retail power to the public at an average of about 3d. per unit for light and 1½d. per unit for power. Another scheme is under consideration for the supply of electrical energy to all the towns in the North Island, and it is anticipated that such power might also be used for the electrification of the railways and the promotion of a system of light railways throughout the country districts, which now suffer from lack of communication because of the difficulty of providing suitable roads.

Growth of Tramways in the United Kingdom. — According to a Parliamentary return just issued the route length of tramways and light railways on public roads open for traffic in the United Kingdom has since 1878 increased from 269 miles to 2,662 miles, the capital expenditure from £4,207,350 to £79,359,758, the number of passengers carried from 146,000,000 to 3,220,000,000 and the net receipts from £230,956 to £5,558,121. The return also includes 13 miles of trackless trolley route worked by the owning local authorities. Of the 286 undertakings 171 belong to local authorities and 115 to companies or other parties. The net receipts of local authorities who work tramway undertakings belonging to them or leased from other local authorities amounted to £1,095,975 on the year's traffic, and they applied £1,299,350 towards the reduction of tramway debt and £514,178 in relief of rates, while carrying £746,749 to reserve and renewal funds. In the cases of four local authorities and seven companies the returns for tramways show an excess of working expenditure over gross receipts. Two trackless trolley systems also show a deficiency. In 25 cases it was necessary to seek aid from rates to meet some part of the charges for the year (including interest and redemption of tramway debt).

Employment in the Engineering Trades.—The monthly report of the Labour Department of the Board of Trade says employment was good on the whole in December, but at the end of the month was somewhat affected by holiday suspensions in the engineering and other industries. There was again a reduction in the number of pig iron furnaces in blast, but employment improved slightly at iron and steel works, and continued good in engineering and shipbuilding. Employment at coal mines remained very good. Wages in the manufactured iron trades continued to fall in consequence of the decline in prices; in other trades the upward movement continued. Trade unions with a net membership of 965,500 reported 25,229 (or 2·6 per cent.) of their members as unemployed at the end of December, 1913, compared with 2 per cent. at the end of November, 1913, and 2·3 per cent. at the end of December, 1912. The changes in rates of wages taking effect in December affected 174,000 workpeople, and resulted in a net increase of £7,800 per week. As regards trade disputes the number beginning in December was 56, and the total number of workpeople involved in all disputes in progress during the month was 59,026, compared with 55,094 in November, 1913, and 30,685 in December, 1912.

The Dangers of Unfenced Gearing.—For neglecting to fence dangerous gearing Wm. Fletcher & Sons, of Notts Road, Derby, were fined £10 and costs by the Borough magistrates recently. The case was a sequel to the accident which occurred at the works on December 30th, when a foreman fitter was killed by being whirled round by unprotected shafting making 120 revs. a minute. He had been standing on a cupboard to take some measurements, and was in the act of descending, when a portion of his clothing was caught, either by a pulley or a projecting set-screw in a collar of the bearing. The cupboard, it appeared, had on other occasions been used as a means of gaining access to the shafting for the purpose of applying oil, and its top was 4ft. 4in. below the gearing, and about 2ft. below the edge of the pulley. Mr. L. Ward, factory inspector, also alleged that despite a warning which he had given the firm, it was the custom of men and boys in their employ to adjust belts and lubricate bearings while shafting was in motion. For the defence it was urged that deceased, who was an experienced man, was guilty of an error of judgment in approaching the shafting, which was situated 10ft. from the floor, and that the firm could not reasonably be expected to guard against such a contingency. In fixing the amount of the fine, the Bench took into consideration the fact that defendants were providing compensation to the amount of £300 for deceased's two children.

Fatal Accidents in Mines and Quarries.—Statistics issued from the Home Office show that during 1913 the separate fatal accidents in and about the coal mines of the United Kingdom totalled 1,210, the death roll being 1,742. In the preceding year there were 1,151 fatal accidents, the loss of life being 1,276. The following table gives the number of fatal accidents during 1913, classified according to their causes and the lives involved under each heading:—

Place or cause.	Number of accidents.	Deaths.
Explosions of firedamp or coal dust	12	461
Falls of ground	591	614
Shaft accidents	73	96
Miscellaneous underground	364	400
Total underground	1,040	1,571
On surface	170	171
	1,210	1,742

In the metalliferous mines the fatal accidents totalled 30, and 31 persons were killed, these figures being a decrease of 10 and 12 respectively, compared with the figures for 1912. The number of fatal accidents in quarries during 1913 was 78, involving the loss of 81 lives. In the previous year there were 71 accidents, and 75 lives were lost.

Trade Circulars and Catalogues.—We have received from Messrs. Schäffer & Budenberg, of Whitworth Street, Manchester, several new descriptive catalogues and price lists relating to self-recording pressure gauges and reciprocating and rotary counters, with accessories and attachments. These instruments include a num-

ber of novel designs for various purposes, and indicate in a striking manner the tendency in all modern engineering work to secure, as far as possible, accurate measurement and permanent records for reference. "Rule of thumb" finds less and less room for exercise, and in a similar way individual observation and memory are being replaced by automatic recording mechanism, whose evidence, in the event of dispute, is uncontrovertible.—From The Coventry Ordnance Works, Ltd., we have received a copy of a new issue of their Small Tool Catalogue, which deals specially with all classes of drills and milling cutters.—The Auto Time Checkers Company, of 63A, Corporation Street, Manchester, send us a catalogue of their various instruments for time recording, tell tale checking, &c., for the use of watchmen, timekeepers, foremen, &c., for checking in various ways cash, goods, and time. From The General Electric Co., 67, Queen Victoria Street, London, E.C., we have received catalogues and price lists of their specialities relating to heating and cooking appliances, electric bells, reflectors, and velveduct conduit tubing, the merit claimed for which is that the interior is as smooth as solid-drawn tube, while the price is much less.—Mr. O. N. Beck, of 11, Queen Victoria Street, E.C., sends a circular describing and illustrating the action of the "Vapor" scale collector.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1912.

Threading dies. Smith. 22212.
Carburetters for internal combustion engines. Morris. 24445.
Power operated portable hammers. Electric Hammers, Ltd., and Scott. 24941.
Process for manufacturing steel or iron. Tischenko & Plauson. 27147.
Percussive hammers and drills. Wakfer & Peck. 27232.
Treatment of ores. Minerals Separation, Ltd. 27323.
Starting of internal combustion engines. Lanchester. 27375.
Preparation of metals and alloys. Strohmenger. 27643.
Methods and means for mixing gas with air for gas furnaces. Hoeller. 29654.
Internal combustion engines. Miller. 29690.
Self acting safety appliance for pit hoist or lift cages. Usher. 29758.
Galvanising or coating metallic sheets. Folland, Morris, and Griffiths. 29801.
Rotary valves for internal-combustion engines. Horsley, Horsley, and Horsley. 29896.

1913.

Steam brake. Dobeson. 31.
Liquid fuel injecting apparatus for internal-combustion engines. Junkers. 141.
Internal-combustion engines. Banks. 180.
Cylinders for internal-combustion engines. Pratt & Pratt. 284.
Variable friction gearing. Christiansen & Clorius. 301.
Fuel supply arrangements of internal-combustion engines. Carter. 314.
Variable-speed mechanism. Huffman. 388.
Driving chains. Yoxall & Wadhams. 435.
Brake apparatus for railway vehicles. Bowles & Bowles. 837.
Manufacture of metal ingots. Howard. 1166.
Apparatus for cutting the grooves of twist drills. Best and Hill. 1260.
Fluid meters. British Thomson-Houston Company. 1722.
Apparatus for controlling speed of winding engines and preventing overwinding. Morton & Shaw. 1754.
Pumps. Mortimer. 2887.
Tool holders for metal turning lathes. Rikof. 2897.
Carburetters. Duverger. 3060.
Driving chains. Harrison, Renold, and Hans Renold, Ltd. 3274.
Apparatus for cleaning flue tubes of boilers. Mackenzie. 3533.
Heat regulators for carburetters for internal-combustion engines. Hans. 5632.
Drop hammers. Grosdidier. 6284.
Mechanical power hammers. Blacker. 6519.
Toothed gearing for steam turbines. Aktiebolaget Ljungstroms Angturbin. 6699.
Ejectors for vacuum brake apparatus. Gresham. 7386.
Furnaces with mechanical stokers of the under feed type. Ratel. 7416.
Regulation of turbines and other steam engines. Vereinigte Dampfturbinen Ges. 7427.
Rotary combustion engines. Tips. 7778.
Supply of working fluid to radial or axial flow turbines. Levermore & Morris. 7841.
Apparatus for casting metals by the lost wax process by means of a vacuum. Ferrari. 8125.
Grinding machines. Cam. 8612.
Hot water injectors. Naylor. 8904.
Sight feed lubricators. Adams. 8905.
Screw propelled vessels and propeller shafts therefor. Coatsworth and Morse. 9386.
Blowers for water tube boilers. Marks. 10035.
Feeding pulverulent material to furnaces. Von Porat. 10214.
Gear wheels. Weisengrund. 10458.
Spray carburetters for internal combustion engines. De Veulle. 11170.
Speed indicator. Hasler Akt. Ges. vorm. Telegraphen Werkstatte von G. Hasler. 12474.
Machines for adjusting and feeding plates in punching and boring machines. Breda. 12581.
Refuse destructors. Compagnie d'Incineration Industrielle. 12668.
Boiler tube cleaners. Bailey. 13350.
Steam generators. Christians. 13913.
Fluid-pressure braking apparatus. Turner. 15205.
Valveless rotary internal combustion engines. Kohler. 16536.
Reversing-gearing. Anderson & Slater. 17765
Optical pyrometers. Siemens Bros. & Co. 17927.
Pipe wrenches. Shepperd & Heller. 18330.
Controlling the draught in steam boiler furnaces. Prat. 18493.
Systems of marine propulsion. Ross. 18977.
Tank ships or vessels. Black. 19379.
Toothed gearing. Van Gulpen. 23124.
Means for admitting air to the manifold intake of an internal combustion engine. Johnson. 23235.
Percussive hammers and drills. Wakfer & Peck. 26790 and 26791.

ELECTRICAL, 1912.

Electric ignition devices. Mordey. 24563.
Electric candle lamps. Garde. 24971.
Electric cable connecting boxes. British Insulated & Helsby Cables, Ltd., and Blades. 29774.

1913.

Gear for electrically operating machine tools. Hall. 19.
Electric incandescent lamp holders. Martyn. 80.
Processes of electric welding. Gruchtel. 331.
Sparking plugs. Runbaken. 333.
Electric measuring instruments of the mercury motor type. British Thomson Houston Company, and Young. 1855.
Machines for winding coils for electrical purposes. Helm. 4091.
Synchronous dynamos. Rosenberg. 6891.
Electric incandescence lamps. Zschocke. 7059.
Trolleys or collectors for electricity. Drake & Burnett. 7213.
High potential electrical insulators. British Thomson-Houston Company. 8675.
Electric controlling valve for air-brakes. Gallusser. 8865.
Ignition dynamos. Mason. 8964.
Electric annunciator and circuit changer. Moore. 10157.
Spark plugs. Dirand. 11737.
Electric motor control system for machines with reciprocating motion. "Vulkan" Maschinenfabriks-Akt.-Ges. 12131.
Electrically propelled road vehicles. Cross. 18819
Commutator trueing devices. Ludwig. 20912.

METAL QUOTATIONS.

TUESDAY, JANUARY 20TH.

Aluminium ingot	90/- per cwt.
,, wire, according to sizes, &c. ......from	117/- ,,
,, sheets ,, ,, ... ,,	112/- ,,
Antimony	£28/-/- to £30/-/- per ton
Brass, rolled	7¼d. per lb.
,, tubes (brazed)	9⅝d. ,,
,, ,, (solid drawn)	8⅜d. ,,
,, ,, wire	7⅝d. ,,
Copper, Standard	£64/17/6 per ton.
Iron, Cleveland	50/9 ,,
,, Scotch	56/9 ,,
Lead, English	£20/10/- ,,
,, Foreign (soft)	£20/7/6 ,,
Mica (in original cases), small	6d. to 3/- per lb.
,, ,, ,, medium	3/6 to 6/- ,,
,, ,, ,, large	7/6 to 11/- ,,
Quicksilver	£7/10/- per bottle.
Silver	26⅛d. per oz.
Spelter	£21/11/3 per ton.
Tin, block	£171/10/- ,,
Tin plates	12/7½ ,,
Zinc sheets (Silesian)	£25/-/- ,,
,, (Stettin; Vieille Montagne)	£25/2/6 ,,

The Mechanical Engineer.
AN ILLUSTRATED WEEKLY JOURNAL. Vol. 33, No. 836

Edited by
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Telegrams: "Scientific," Manchester.
Telephone No. 6655 City.

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The Production of Power.

THE production of power is a question that concerns more or less all engaged in manufacturing industries, and to some is of great importance owing to the large proportion which the cost of power bears to other costs. In his paper on this subject before the Manchester Association of Engineers on Saturday last, Mr. Edward G. Hiller discussed the question not only in its broad aspects as regards the allocation of power to various industries throughout the United Kingdom and its bearing on national coal supply, but also in detail as regards the various prime movers adopted to utilise this, which is the primary source of all industrial power, if we except imported oil, which, relatively speaking, is insignificant. The figures collated from various official sources, as well as from data available to him as the chief engineer of one of the large boiler insurance companies, have involved a good deal of careful analysis, and lead to some interesting and instructive conclusions. It is our intention to reproduce the paper in full, so that those specially interested may follow it in detail, but as the paper is a lengthy one it may be of convenience if we here present its more salient features.

Prior to the census of production of the United Kingdom taken in 1907 nothing approaching complete figures, as regards power production, was available, and the report on this is the source from which Mr. Hiller has drawn much of his information respecting power production as a whole. Statistics in regard to coal output have been available since 1873, and as coal is the source of power, the consumption per head of population, apart from improved methods of utilising it, is, roughly speaking, a measure of our progress in the material comforts which constitute modern civilisation. At the date named the home consumption was 113 million tons per annum, or at the rate of 3·5 tons per head. This amount, if we except minor fluctuations, has steadily advanced until in 1911, the last year for which figures are available, it

amounted to 185 million tons or 4·8 tons per head, an increase of over 60 per cent. Coincident with this increase in the raw supply of energy steady advances have been made in all methods of conversion, both as regards the production of steam and its utilisation in prime movers, and hence the progress in comfort has been much greater than these figures would indicate, and the study of the various factors which contribute to this end is probably the most interesting portion of the paper.

No development has been more conspicuous during the last 20 years, or furnished more complex problems for study, than the varied types of prime movers that have come into being; and it will probably surprise many people to learn from the census in 1907 that out of the total of about 10½ million horse-power distributed amongst various industries no less than nine-tenths was then developed by reciprocating steam engines, though the census of 1912, which is in preparation, will probably reveal considerable advance in the rivals to this oldest of prime movers. Changes, even when merit justifies it, must obviously in the nature of things be rather slow. A new power plant may offer considerable saving in replacing an older one, but this is often not great enough to justify the scrapping of it, especially if it is in good condition, and thus their inroads as competitors is largely confined to new installations.

The total *steam* power of industry for 1907 was, roughly, 9·6 millions indicated horse-power, and for the year 1911 Mr. Hiller gives 10 millions indicated horse-power as a fair estimate, and on the assumption that steam engines on the average use 6lbs. of coal per indicated horse-power per hour, and work 2,500 hours a year, 67 million tons would be absorbed for power purposes in the latter year, or rather more than half of that consumed for all purposes in the principal industries. The cash importance of the economies in power production varies in different industries, but if, as he assumes, mechanical power costs 10 per cent. of the total in any industry, a saving of 10 per cent. in the cost of power will amount to 1 per cent of the total cost of production, and taking his basis of 6lbs. of coal per indicated horse-power per hour, equivalent, say, to 6·7 tons of coal per annum, and coal at 12s. per ton, this would mean £4 per indicated horse-power per annum, or 40 millions sterling for 10 million i.h.p., the estimated amount for 1911. Since the latter amount is 2½ per cent. of the total production of the country, it would appear that between 2 and 3 per cent. is the approximate average importance to industry of the fuel cost of power production.

In the conversion of coal into mechanical energy by steam prime movers the boiler is the first step, and it is interesting in this connection to note the evolution of the types that are mainly employed. No national census of these is available, and the writer of the paper, in forming his estimates, has had to rely upon an analysis of the figures relating to boilers insured with his company. They may not be strictly accurate, but are doubtless sufficiently so for purposes of general comparison, and in this respect are instructive. At the present time in this country the Lancashire type of boiler is the one most generally employed for large steam installations, and although it meets in certain directions with a serious competitor in the water-tube type, and the percentage of the actual number employed has, as regards actual numbers, declined from 36·8 per cent. in 1895 to 32·6 per cent. in 1913, it still retains its pre-eminence, for in considering these percentages it should be borne in mind that during recent years the tendency has been for individual boiler units to increase in size more rapidly than the decline in percentage of numbers. For example, during the period 1880-90 the average diameter was about 7ft., with a grate surface of 33 sq. ft., while in the next decade the average diameter, roughly speaking, was increased to 8ft., with a grate surface of 37 sq. ft., and during the period 1900-10 the diameter reached to about 9ft., with a grate surface of 43 sq. ft. This, it may be remarked, is about the maximum—not that larger Lancashire boilers could not be made, but that considerations of railway carriage which in many cases is necessary forbid further growth.

The tendency to increased size in boiler units, especially in large installations, just noted, is further reflected in the diminished use of Cornish boilers, which, as regards general construction, are similar to the Lancashire, though they only contain one internal flue tube instead of two. In 1895, according to the figures available to Mr. Hiller, Cornish boilers formed 22·8 per cent. of the whole, whereas in 1902 they were only 18·3 per cent., and in 1913 had dwindled to 12·7 per cent. Curiously enough, vertical boilers, which are often of small size, show, in contradistinction to Cornish and Lancashire boilers, a tendency to increase in number. In 1895 the percentage of these boilers insured with Mr. Hiller's company was 16·5 per cent., whereas in 1902 the percentage had increased to 20·3 per cent., and in 1913 to 24·3 per cent. This growth is hardly what one would have expected in view of the fact that this class of boiler, often used for driving small engines, has been largely replaced by gas engines and electric motors. On the other hand, it was a class which, some years ago, often escaped the purview of insurance companies, though it has since been largely brought under their charge by the operation of the Factory Act and the Boiler Explosions Act. It will be seen, therefore, that in making comparisons the percentages given must not be accepted too literally. One satisfactory feature in connection with boiler evolution is the steady and unmistakable decline of externally-fired boilers, notably those of the plain cylindrical egg-ended and Rastrick types. The first used formerly to be largely employed at collieries, and the latter, which is of a similar shape but set vertically, and fitted with a central internal flue, at ironworks. The internal flue had two or four connections to the external shell for connecting to a corresponding number of furnaces, the waste gases from which formed the source of heat. These two types, some 20 years ago, were a frequent and lamentable source of disaster, owing to the intense and variable stresses set up in the external shell, which is in a state of tension, by the method of firing, and it is a knowledge of the loss of life which was formerly entailed by the use of these boilers that renders it a pleasure to record the fact that the latter type is practically discarded, and now constitutes only 0·5 per cent. of the whole, while the horizontal plain egg-ended boiler has dwindled from 6·7 per cent. in 1895 to 2·3 per cent. in 1913.

The most remarkable feature of boiler evolution during the last 20 years is the way the Water-tube type has come into vogue. In 1895 it constituted only 1·8 per cent. of the total, whereas last year the proportion had risen to 5·3 per cent., but this while representing the increase in numbers, does not represent its real growth, inasmuch as it is possible with boilers of this type to increase their power by greater height without material increase of floor space. The competition between the Water-tube and Lancashire types is not only interesting, but illustrates the way in which special features differentiate boilers for particular purposes. In textile mills the Lancashire still reigns supreme, mainly because, as

a unit, it is often sufficient to meet the power demand, it is very accessible, it is capable of using dirty water to a certain extent, and can be easily constructed to carry pressures up to 160lbs., and which very high economy can be secured in reciprocating steam engines, especially when used in conjunction with a superheater and Economiser. In electric power stations, where ground space is often very valuable, and where turbines are often installed and pressures up to 200lbs. or 250lbs. on the inch used with boilers that can be rapidly got under steam and capable of developing large power on a limited area, the water-tube type, with its external furnace, is becoming a standard type. Its contracted water spaces, however, necessitate the use of pure water, free from scale-forming ingredients or corrosive properties, and in making comparisons between the relative powers of this and other types, it has to be borne in mind that increase of heating surface in a water-tube boiler is merely a question of height. This fact has been largely utilised, for whereas in 1890 the power of an ordinary water-tube boiler was about equal to that of a Lancashire, with an evaporation of 5,000lbs. to 6,000lbs. of water per hour, they are now frequently constructed with an evaporation of from four to five times this amount.

Power production in steam engines or other prime movers furnishes problems of greater complexity and interest to mechanical engineers than those usually associated with boilers, and Mr. Hiller's treatment of this portion of the subject, dealing as it does with questions of breakdowns and the lessons to be derived from them, culled from his special and wide experience, will probably be read with the greatest interest. It is only possible within the space here available to touch upon a few of the more interesting of these, and to all interested in the construction of prime movers, whether operated by steam or gas, we would commend a careful perusal of his observations in detail. The gradual evolution of the various types is illustrated by him graphically and in a manner that enables one to see at a glance the date, progress, and in some cases decline in their use, such as has accompanied the beam engine and the single-acting high-speed central valve engine. A discussion of the merits of various prime movers must inevitably be more or less intricate and thorny. They cannot be determined by considerations of fuel economy alone. Reliability and freedom from costly breakdowns count for a great deal in industrial operations, and a glance at the analytical tables given in the paper is particularly illuminating, and explains why the oldest type of prime mover—the reciprocating steam engine — still rules in the majority of cases. Notwithstanding its comparative antiquity, improvements in the directions of increased pressure and superheat enable it to provide power on terms which compare favourably with the best of its rivals. To permit of a full comparison, the table must be studied in detail, but the more prominent facts may be noted. Taking an installation of steam engine, boiler, and superheater, the average steam consumption for units up to 250 h.p. works out at 13·3lbs. per indicated horse-power hour, or 0·137 pence per brake horse-power hour, assuming an evaporation of 7½lbs. of water per pound of coal at 13s. per ton, and an engine efficiency of 90 per cent. For 1,000 i.h.p. the fuel cost on the same basis is 0·123 pence. Comparing this with the steam turbine of 1,000 i.h.p. (670 kw.), the fuel cost of the latter works out at 0·111 pence per brake horse-power hour. This diminishes with increase of size, and for 5,000 i.h.p. (3,500 kw.) becomes 0·1 pence. The fuel cost of gas engines depends, of course, on the nature of the fuel used, but with town's gas at 1s. 9d. per cubic foot it works out, for engines of about 50 b.h.p., at 0·313 pence per brake horse-power hour. With suction gas, using anthracite at 30s. per ton, the fuel cost is 0·193 pence, and is further reduced to 0·084 pence using producer gas from bituminous slack at 12s. per ton. In Diesel engines, notwithstanding that the fuel consumption is only 0·44lb. of oil per brake horse-power hour, and thus only about one-third the amount for the cheapest gas engine, the fuel cost in pence per brake horse-power hour is 0·212, or three times that of the gas engines, owing to the high price of oil, which at present is some £4. 10s. per ton. This shows how misleading comparisons based on fuel quantities alone may be if regard is not paid to cost of fuel, while this itself is not sufficient in judging of suitability of a prime mover for any particular service. Many factors have to be considered, and that of liability and cost of breakdowns is not of least importance.

In this connection another table in Mr. Hiller's paper is most instructive. It gives a record of his experience as regards the liability of prime movers of various types to breakdown, and also their relative cost. Taking steam engines as unity, then gas engines up to 14in. diam. appear safer, since the number of breakdowns is represented by 0·6, and breakdown multiplied by cost by 0·24. With this exception, however, steam engines shine by comparison in both respects, and help to explain the difficulties which face its rivals, and the reluctance which power users who have to pay every item, whether it be capital charge, depreciation, running cost, or upkeep, display towards new types unless strong reasons can be furnished. For instance, pursuing the above comparison, it would appear that gas engines over 14in. diam. rapidly increase their liability to breakdown, owing to heating troubles and the obstinate adherence of makers to defective designs, especially as regards the trunk piston and the connecting rod, the number of failures being 2·82 times that of steam engines, or, multiplying number by cost, 3·01. Steam turbines also furnish instructive figures, the number of breakdowns being 3·36 times, while number multiplied by cost is no less than 6·3 times that of steam engines. The nominal simplicity of the turbine is often dwelt upon, but the ugly side of their use revealed by these figures is, as a rule, only seen by insurance companies who have to meet the bills for repairs. Latterly the Diesel engine has come very much to the front, and for many purposes has doubtless a great future, but its practical working is at present attended with serious risk of breakdowns, the number which occurs, compared with steam engines, being three times as great, while the cost of these is 3·75 times. We have discussed some of the special difficulties connected with their working at various times, and notably the small clearance between piston and cylinder diameters, owing to the high compressive pressures required. No doubt the inherently structural difficulties associated with the steam turbine, the Diesel engine, and the large gas engine will in process of time be surmounted, but this process is not accelerated by the refusal of makers to look the difficulties fully in the face. Comparative figures of the kind we have quoted shed a good deal of light on their magnitude, but are only known to a few, and not easily obtainable, and for this reason power users and engineers generally will, we think, be grateful to Mr. Hiller for their publication

WATER-RAISING AND MEASUREMENT.*

BY W. H. BOOTH, F.G.S.

WATER-RAISING, omitting primitive machines, is carried out by means of machines which may be classed in six divisions, represented by the scoop wheel; the displacement rotary pump of the gas exhaustion or other similar type; the centrifugal pump and the bucket pump, which may be made either with a bucket, a plunger, or both, or with many buckets on a chain run continuously up a pipe; by the air-lift pump; or, as a class alone, the Humphrey gas pump, in which the duties of the pistons of both the pump and the actuating

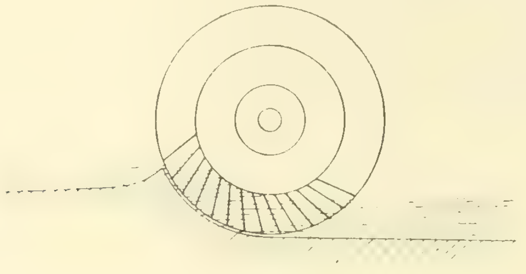


FIG. 1.

gas engines are filled by the water to be raised. Needless to say, water-raising is done under so many conditions that considerable judgment must be used in selecting the machine proper to each condition. Under very heavy pressure the bucket of a reciprocating pump takes the form of a ram. The extreme case is the small ram of the pump of an hydraulic press. The more moderate case is the boiler feed pump. The scoop wheel, Fig. 1, is a very low breast water wheel reversed, and, as they may be seen in Holland, where they are used in lifts of about 4ft., they are very efficient machines to freshen up the Amsterdam canals—that is to say, to remove the stagnant water when the canals are supplied with clean water from the sea or some land drain. The scoop wheel is large and slow of movement. The floats are not radial, but so inclined that the edges somewhat face the stream to be raised and discharge at a convenient angle on the upstream side of the low lift, so that the water in dropping out of the wheel gives a minimum of back pressure.

The growing certainty of high-speed machinery has led to the gradual displacement of both scoop wheels and bucket pumps in land drainage works by the centrifugal pump. The basis of design of this pump is the principle of gravity. Any falling body acquires a velocity about $8\sqrt{H}$ or $V=\sqrt{2gH}$—where V = velocity in feet per second, H = height of fall in feet, and g = gravity or 32·2ft. per second. Thus a fall of 4ft. gives a velocity of 16ft. per second, and the tips of the vanes or blades of a centrifugal pump must usually move faster than this velocity if they are to raise water 4ft. Thus on a lift of 100ft. the tip velocity must exceed 80ft. per second.

But Rankine gives as the velocity of the tip of a blade the expression $\frac{V^2}{g}=h$, or $V=\sqrt{gh}$, for, in a vortex, not only is there the energy due to the velocity of the water, but that due to its centrifugal pressure, and the result is that in well-designed pumps the height pumped is greater than the tip velocity would give alone.

Only large pumps appear to be capable of utilising the principle of the free vortex as described by Rankine, and usually the velocity must exceed $\sqrt{2gh}$, for not only must the actual head be overcome, but also an additional head which represents the velocity of delivery of the water, and, still further, the additional friction head. For best efficiency the runner should discharge to the outer spiral through a divergent whirl chamber with guide plates so as to approximate to a reversed turbine, the energy of the fast-moving water being converted thus into pressure energy in place of being lost in eddy production.

Centrifugal pumps are applied to higher lifts by being placed in series, one wheel behind another, the pressure equivalent to the great head being obtained in stages, the sum of which amounts to the total pressure of the head to be surmounted. Thus each runner, except the first, receives its water under pressure, and adds a further energy to it.

The centrifugal pump is a machine with which many engineers are insufficiently familiar; it is not positive in its action. Close the delivery pipe of a bucket pump, and something must burst or break or stop. Close the delivery of a centrifugal pump, and the engine which is driving it will run away. The reason is that the pump runner simply rotates with the casing full of water as a plain disc. No water is delivered; no work is done; friction alone is overcome. A contractor was once brought to ruin because an engineer specified a certain size of centrifugal pump; he specified the height at which a specified quantity of water should be delivered; he specified the power of the pump motor, and he specified the efficiency. To deliver the quantity and no more the pump had to be throttled. This reduced the efficiency. If run unthrottled it delivered so much water that the motor ran hot through overload. The things specified were incompatible and the poor contractor was ruined by this engineer, who was perfectly good in his intentions and believed that he was being badly treated by the contractor. The specified askings were impossible of attainment in so disproportioned a scheme. It was wrong to tie the contractor's hands so far, for he had a right to assume that the engineer knew, or if he had been left with a free hand he could have obtained advice from some engineer who did know, and he would then have put in a pump little over half the capacity of the pump asked for.

The rotary pump other than the centrifugal takes many forms. In one, that favourite form of rotary engine with a sliding shutter in a cylinder, as used in Beale's gas exhauster, has been a success as a pump, if a failure as an engine. The Roots type of pump, in which a pair of two-lobed or three-lobed rotors are run together in a Fig. ∞ casing, has been greatly used, and there have been, and are, many forms of screw pumps for which special claims are made in respect of their capacity to deal with mud. Sometimes pumps apparently rotary, are merely so many little plunger pumps embodied in a rotary part, the plungers being actuated by some cam path about which the rotor turns. These are really bucket type pumps, and have a useful field of limited area.

The choice of a pump will be influenced by the quality of the liquid to be raised, by the height of the suction and delivery, and by the motive power available, for upon the motor must the style of the pump depend to some extent. Thus any form of rotary pump may be driven by a steam engine, a gas engine, a turbine or an electric motor, and the connection between the motive power and the pump will either be direct or through a belt, rope, chain, or worm gear.

The air lift pump, Fig. 2, sometimes employed in boreholes, has the advantage that it will lift more water from a borehole than can be raised by any single-barrel pump. Its disadvantages are that it absorbs several times as much power to drive it; that often it necessitates a needlessly deep borehole to contain it, for the length below the pumped water level must be usually sixty per cent. of the total height of delivery above the air inlet. Then the air-charged water is very corrosive, and soon destroys the rising mains and other pipes, heating apparatus, &c. Its action is simple: air is pumped down the borehole and enters the rising main near its lower end. The water and air in each 100ft. of this column are less in gravity than each 60ft. of the solid water outside this column of froth and the acting agent is the external water, and this becomes froth when it enters the rising main with the stream of compressed air. The serious inefficiency of an air lift arises from the fact that air compression is a very inefficient process, and there is probably very great slip between the air and the

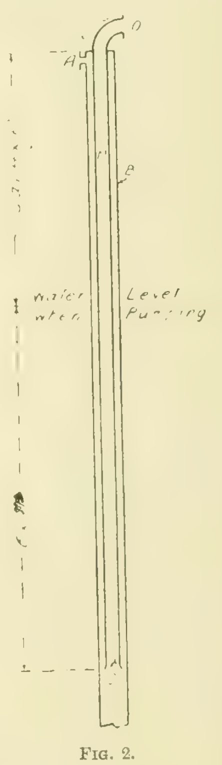


FIG. 2.

* Abstract of paper read before the Association of Engineers-in-Charge.

water in the rising main, especially in high lifts. When the lift is considerably above the surface, an auxiliary mechanical pump is required and the so-called simple air lift is found to resolve itself into a room full of motive machinery, air compressors, reservoirs, auxiliary pumps and accessories, which compare badly with the simple and efficient single barrel pump, working for a third or a fifth of the motive power, and occupying an eighth or a twelfth of the space.

In all cases the water level in a well must fall more or less while it is being pumped, and the starting pressure of an air lift pump must exceed the running pressure by the amount of this difference of head. In Fig. 2 is shown the air-lift pump in outline. In this case the air is sent down between the casing of the borehole and the rising main. In other cases a small air pipe is carried down in the space and delivers at C, the air pipe end being turned up an inch or two inside the main, or the air pipe may be inside the main. Where the pump must extend down the borehole below the points at which water enters this from the rock fissures, the pump must not be too close a fit in the borehole, or there will not be room for the water to flow down the narrow annular space to reach point C.

Various devices for admitting the compressed air to the foot piece have been evolved and probably serve some purpose of the touting salesman, but common-sense hardly supports belief in any arrangement of air bubbles in a rising main being influenced by any system differing from a plain upturned jet pipe or the escape of air round the edge of the main foot.

Generally in pumping water the aim should be to maintain it in continuous movement in one direction, at a velocity as uniform as possible and to avoid sharp turns and strangled passages.

With reasonable care the theoretical horse-power, or the water horse-power, will be amply provided for by a motive power 50 to 100 per cent. greater. For small work it is usual to provide double the water horse-power, because small gas engines are so very like toys, and small gas producers are mere toys. But even with these small affairs it will be found often that one producer will drive two engines and run with a greater number of cut-outs than when driving only one engine. This merely proves that a heavier draught is required to attain the more efficient gas-making temperature. With good work the double ratio of power to work gives a rather extravagant margin of power.

Despite the remark just made about maintaining the water in continuous one-way movement it is remarkable that the latest and simplest pump works by virtue of a mass of water which oscillates to and fro in a long pipe. The Humphrey gas pump is, of course, referred to. In it water does the work which is otherwise done by the piston rods, crossheads and flywheels of the steam and gas engine and the piston pump. It has none of these details, for it possesses only gas inlet and exhaust valves and the water valves. In this pump a gas and air mixture is exploded in a chamber, Fig. 3, and sets a column of water in motion along a pipe and up a riser. The gas expands to below atmosphere and the exhaust valve opens and locks open; the water column returns, closes the exhaust valve after expelling most of the gases, and compresses the remainder above exhaust valve level. This compressed gas again propels the water forward, and air, gas, and water are drawn into the partially vacuous space. Again the water returns, and the valves being now all shut the gas mixture is compressed and fired and the above cycle repeated, the sucked-in water being expelled at the head of the riser by each explosion. At Chingford each of the four large pumps will pump 50,000,000 gallons per day to a height of 25ft. or a quantity equal to the entire supply of Manchester and Salford. The ability to expand below the atmosphere and the absence of mechanism combine to produce great economy and fit this pump for great works of drainage and irrigation. It will work to lifts of 300ft. and can thus be employed to produce artificial waterfalls for working hydro-electric plants, thus enabling those engineers who are afraid of big gas engines to utilise waste blastfurnace gas for power purposes on lines possibly even more economical than by electric generators driven by rotative gas engines. In the Humphrey pump the velocity with which the water is driven along the body pipe will depend upon the pressure of explosion above atmosphere and the weight of water to be moved.

This pump can be made in many forms. It may be two or four stroke in cycle, single or double chambered, an air compressor, or at once both a pump and an air compressor. There is no mechanism except valve gear, and this only extends to some light locking apparatus, for the valves open automatically.

The larger pump at Chingford has the general form of Fig. 3, and consists of a horizontal pipe 6ft. diam. and 61ft. 9in. long, carrying a vertical column A, the head of which is the gas explosion vessel, and carries all the valve gear. This chamber, about 6½ft. diam., stands on the water inlet column which is 10ft. long and 7ft. diam., made up of about 16 rings of simple inward opening flap valves with light helical springs to shut them. This length of 10ft. stands on the base of a large pit into which flow four pipes from the intake from the River Lea. The horizontal pipe is nearly 62ft. long, to the great riser which is of boiler plate and tapers from 6ft. diam. to 15ft. at a height of 53ft. 6in. above the horizontal centre line. Out of this riser C leaves the 4ft. discharge pipe to the reservoir. At the top of the combustion chamber there is an air trunk for scavenging air S. Immediately round the base of this trunk stands the circle of eight scavenger valves hung on light closing springs. On a larger circle stand next the gas inlet valves, similarly hung, and then, on an outer circle, eight air valves of the same design. Just below the curved dome of the gas

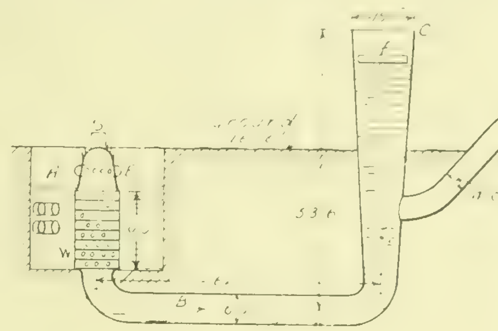


FIG. 3.

chamber stand out the bonnets of the 16 exhaust valves E, which discharge to an outer belt through light non-return valves.

Round the air trunk a light brass ring is carried on a plain bearing, and is rotated to and fro through a small angle by means of a tangent rod worked from a little water pressure device actuated by the water. Eight other tangent rods are attached to this ring. These work the little locking bars on the scavenging, gas inlet, and air inlet valves, the first being locked when the last two are unlocked, and vice versâ. The rods also lock and unlock the exhaust valves which open into the gas chamber, and are held open by light spring pressure.

Watching the pump at work this is what appears to happen. The gas explodes and drives the water along the great pipe, and near the top of the tower C, the water wells up about 3ft., lifting a heavy circular pinewood float *f*, an anti-splash board. All the time, steadily, water flows out at D. The mass of water moves many feet past the water valve W, and the gases expand below atmosphere, and about 12 tons of water enter the pump (say, 30,000lbs.) at the valves W. Also, being unlocked by the last surge up of the water column, acting to move the tangent ring, the scavenging valves open into the partial vacuum, and clean air enters and pushes the burned gases down to the exhaust valve level. The water tower now sends back the water by gravity and pushes out the exhaust gases, the exhaust valves having been opened by their light springs into the gas chamber and the secondary non return valves remaining always shut against any return of the exhaust when the primary exhaust valves are opened into the partial vacuum.

The gas chamber is now empty, the exhaust valves are closed by the return of the water, the springs close the scavenger valves; the rising water, through the device named, locks these two sets of valves, and the water, still forcibly rising, compresses all gas and air above exhaust level. The pressure of this air then again drives forward

the water; it rises now only a few inches in the coned tower C, and again creates a partial vacuum in the gas chamber, so that the gas and air valves now let in their charges, and the partial vacuum is destroyed and the valves are then closed by their springs. The water again surges back on its fourth swing, and compresses the now combustible charge which is electrically fired, and the cycle is complete. The second rise in the tower is only perhaps 8in. or 9in. The water movement in the tower is, of course, only about a fifth to a sixth that in the pump body B. The actual ratio is concealed under the constant flow at the 4ft. pipe D, which flows steadily all the time. Every valve opens and closes automatically. The only duty of the mechanism of the tangent rods is to slip into place the little locking bars which hold the valves shut until they are wanted to open.

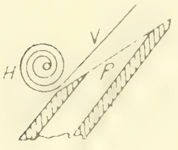


Fig 4.

In the old Cornish pump the water was forced up by the descent of heavy pump rods to which the pumps were connected at different mine levels. These rods were hung to one end of a great beam, to the other end of which was hung a steam piston. This piston was forced into the vacuous cylinder base by the admission of atmospheric steam above it. It lifted the rods and these descended and did the work (*a*) of raising the water, (*b*) of transferring the steam through the by-pass to the underside of the rising piston. The cylinder base was then opened to the condenser, and the above cycle repeated. In later work the pumping engine of this type had a crank and flywheel. These obviated the need for the spring beams, which checked any too vigorous action of the vacuum stroke in lifting the rods; it enabled the engine to do its work with the least possible steam expenditure, though it involved more bearing friction. It was the great size of such engines and their cost and elaborate foundations that favoured the introduction of centrifugal pumps for low-lift work of large output with small high-speed engines, and this, too, in spite of the inferior efficiency and economy. Such pumps have been employed in Egypt, notably at Khatatbeh, where five Farcot pumps of about 12·6ft. diam. raised water about 10ft. when running 32 turns per minute. Thus the tip velocity is 21ft. per second, the suction tube nearly 10ft., and the outlet 5¼ft. diam.

Certainly, for low lifts—probably for any lifts within its capacity—the Humphrey gas pump is at once the most economical, both in first cost and maintenance, as well as in fuel, for it secures at once the abolition of nearly all mechanism either of the motive power or of the pump, and it secures the higher thermal efficiency possible with gas power and the additional expansion below atmosphere.

Whether in passages, or in the body of a pump, it is essential that there should be no sudden changes of cross-section or direction. Thus a centrifugal pump starts with a large inlet gradually reduced to deliver the water without shock to the runner, and this, in the best designs, delivers it to a set of guide blades in a whirl chamber, and so to the outer spiral and final delivery.

Valves, if only to prevent flow back of streams moving continuously, should open clear of the passage way. For reciprocating pumps, they must close of their own natural elasticity. One of the best is the Gutermuth valve, Fig. 4, a strip of metal V, which closes on an outlet port P, which is sloped to give a large opening for a small valve movement and whose hinge H is formed from the valve strip itself wound like a clock spring, and thus very easy and elastic.

The driving of pumps by gears, ropes, belts, or chains, as connecting pieces between a rotary motor and the pump gear, does not call for much discussion. Gears, if well made, probably have superior efficiency to either belts or ropes. Belts are usually too thick and too narrow. For small machinery, the double thick belt is a mistake. It should be thin, wide, and pliable. Ropes and chains require a clutch for starting, and the belt avoids this. The loose pulley should run on a collar, not on the shaft, and it should be ½in. less in diameter than the fast pulley, so as to permit the idle belt to shrink and rest when off duty.

It is useful when dealing in water questions to acquire a stock of useful figures for mental calculation. Thus, a yard of water in a circular pipe of D inches diameter weighs D^2 pounds. A 4in. pipe holds 16lbs. or 1·6 gall. per yard. Hence follows the rule that the square of the diameter of a pump gives the yield in gallons per minute if the stroke is 18in. and the speed 20 working strokes per minute. Thus a 6in. pump yields 36 galls. per minute, or 2,160 galls. per hour. Suppose the stroke is 24in., it is easy to divide 2,160 by 3 = 720, and add this mentally to 2,160 = 2,880 galls. per hour. If also the speed is 18 instead of 20, take a tenth of 2,880 = 288 and subtract it from 2,880 = 2,592 galls.

The circular inch is a useful measure, for upon a circular inch of area a 1ft. column of water gives a pressure of just over one-third of a pound, a figure easier to work with mentally than the 0·43lb. per square inch.

The amount of water raised by pumps is told with fair approximation to accuracy by counting the strokes; but the Venturi meter can now be used, with little added obstruction to flow, to give much closer accuracy. This meter, Fig. 5, is a modern application of a curious phenomenon known for many years. Where a jet of water or a stream is compelled by following pressure to hurry itself through a narrowing passage, its tendency to exert lateral pressure is reduced, and it is possible with a well-proportioned narrowing throat actually to cut away a pipe, and the moving jet will jump the gap and continue in the pipe to move against pressure without escaping laterally. For very large supplies the Venturi meter gives accurate results. It works on the principle that, if a stream of water changes its velocity in a closed pipe of varying cross-section, the pressure it exerts laterally will be varied also. The Venturi meter consists of a short throat in a pipe, and joined to it by conical lengths. These compel the water to travel gradually more quickly, and the throat velocity is several times that in the pipe at each side of it. Pressure gauges on the pipe and on the throat will show different pressures, that of the throat jet being a minimum. This pressure difference is recorded in terms of gallons passing.

In order to keep continuous records of the air-pump discharge from a surface condenser Mr. Lea brought out his recorder. It consists of a tank, into which the discharge is

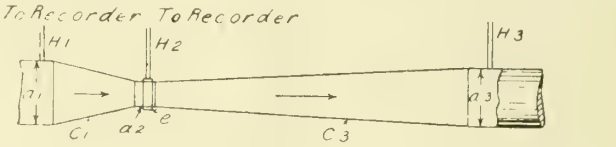


Fig. 5.

delivered, and of a chamber which contains a float so connected to a drum with a spiral groove that the pencil of a recorder, which pencil is moved by a stud in the spiral groove, traces a line showing flow velocity on a paper drum. The integration of the diagram gives the total flow in a given length of time. The height of the curve shows the flow at any instant.

North-east Coast Institution of Engineers and Shipbuilders' Scholarship.—A scholarship will be offered for competition among graduates of the North-east Coast Institution of Engineers and Shipbuilders in September next. The scholarship is tenable for two years, and is of the annual value of £50. The scholarship will be awarded on the results of an examination held in Newcastle during the month of September, simultaneously with the matriculation examination of Durham University, in the following subjects: (a) English, (b) mathematics, (c) experimental science. Every candidate for the scholarship shall be a British subject and a member of the graduate section of the Institution of not less than one year's standing, and shall have served or be serving an apprenticeship on the North-east Coast. Candidates for the scholarship must forward a written application on the prescribed form to the Secretary of the Institution, on or before August 1st. Full particulars and detailed syllabus of the subjects of the examination may be had on application to the Secretary, North-east Coast Institution of Engineers and Shipbuilders, Bolbec Hall, Newcastle-on-Tyne.

DRYING CYLINDER EXPLOSION AT BRADFORD.

Board of Trade Enquiry.

Mr. A. H. Hudson, K.C., and Mr. John McLaren, who had been appointed by the Board of Trade as a formal court of enquiry to investigate an explosion which took place at the Valley Dyeworks, Bradford, in April last, and killed a man through the bursting of a drying cylinder, delivered judgment on Saturday, the 24th inst., at the Bradford Town Hall.

Mr. Hudson said that he and his fellow commissioner found that the owners (Messrs. J. R. Denison & Co.) were not to blame, but the makers of the machine (Messrs. E. Hoyle & Sons, Halifax), Mr. Arthur Silverwood (works manager), Mr. James William Banks (works engineer), Mr. Arthur Kendall (foreman in the dyeing and mercerising department), and Michael O'Dea (who was killed), all contributed to the explosion, and were all more or less to blame for it. The wonder was, added Mr. Hudson, that the explosion did not occur before, because it seemed to the Commissioners, although the evidence was not at all satisfactory on the point, that the machine must have been worked at a pressure of steam of over 15lbs. During the six and a half years the machine was running—up to the time of the explosion—the safety valves were never overhauled and never taken apart; and no one ever made a thorough examination of the cylinders. O'Dea stopped the machine in the course of his work without turning off the steam, contrary to the rules, and this contributed to the accident.

For guidance as to the future use of the machine, the Commissioners suggested that (1) the area of the outlet of the safety valve should be large, because of the low pressure of the steam in the machine; (2) periodical tests should be made by hydraulic pressure; (3) to enable this to be done without dislocating trade it might be desirable to have spare cylinders.

In conclusion, the Commissioners answered the questions of the Board of Trade solicitor as follows:—

(1) Was the machine supplied with proper and adequate mountings?—No.

(2) Were the mountings properly fitted and in the best position for the purpose for which they were used?—No.

(3) Was the machine, including the cylinder which exploded, periodically inspected by a competent person?—No.

(4) Were proper measures taken by the owners and works engineer to ensure that the machine was worked under safe conditions?—Proper measures were taken by the owners in appointing a competent engineer, but nothing was done by the engineer to examine the work done by Hoyle & Sons or the mountings which they had fitted.

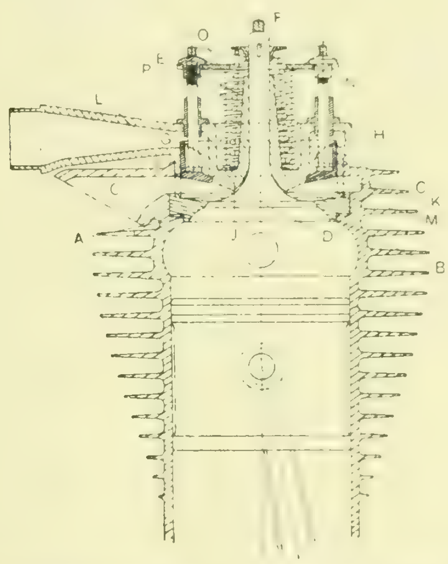
(5) Was the machine entrusted to a competent person or persons?—With regard to O'Dea a competent person was put on to look after the machine, but he had practically no experience of the particular machine, and he did not know that the safety valve was overloaded, while the men working under him were not performing their regular duties.

No order was made as to the costs of the enquiry.

VALVE ARRANGEMENTS FOR INTERNAL-COMBUSTION ENGINES.

The accompanying illustration shows a sectional view of an internal-combustion engine, patented by Mr. W. A. James, Station House, Cornwood, Devon, and designed with a view to simplify the valve chamber and the valve passages leading to the cylinder, so as to ensure the free flow as well as avoid the retardation of the passage of the gases through the action of "pockets" or narrow ports. The cylinder is provided on its end with an aperture A of comparatively large diameter to that of the cylinder so that when the valve seat ring is in position it gives an enlarged area for the escape of the spent gases. The wall of the aperture is recessed to receive the annular flange of the valve seat ring B. The end portion of the cylinder is extended and enlarged at C to form a passage around the end of the valve casing. The main valve D opens in the cylinder and when closed abuts on the seat of the valve seat ring B. This valve is of the mushroom type, and is closed automatically by a spring E when released after being opened by the rocker F of the controlling mechanism. The cavity G in the valve casing H above the main valve D is cylindrical, which, with a circular portion J projecting concentrically into the cavity, forms the working face for the auxiliary valve K. A shoulder is formed concentrically around the circular projection J against which the auxiliary valve K abuts when closed, thus serving as a valve seat. A passage C is formed in the extended end of the cylinder casting around the outside wall of the larger circumference of the cavity G, near the end of the cylinder of the engine, through which the exhaust gases pass from the aperture of the valve seat ring B, controlled by the main valve D to a silencer or to the atmosphere. Above the passage C is a second passage or port L formed around the larger circumference of the cavity, through which the combustible mixture passes into the cavity of the valve casing H when the auxiliary valve D is opened. The casing M has port holes formed around its circumference so as to ensure an easy flow of the gases. The auxiliary valve is in the form of a concentric ring K having a vertical annular flange around its outer edge which when the valve is fully opened, to admit the combustible mixture to the cylinder, closes the exhaust passage C. The valve rods N work in guides fixed to the casing. These rods are lifted by the bridge piece O by the action of the spring P after the valve D has been opened and again released.

The arrangement is such that when the valves are in



Valve Arrangements for Internal-combustion Engines.

operation, and the piston is on the outward stroke to draw the combustible mixture into the cylinder, the main and auxiliary valves are opened for admitting of the combustible mixture passing into the cylinder. On the return or compression stroke of the piston, the main valve D and auxiliary valve K are closed, and remain so during the outward stroke of the piston caused by the firing of the combustible mixture. On the succeeding return or exhaust stroke of the piston the auxiliary valve K is closed, opening the first passage C to the cavity G of the valve casing H, and the main valve D is opened, permitting the spent gases to exhaust. During the exhaust stroke, the auxiliary valve K is being moved to open the passage L for the combustible mixture, but before this passage is opened it has to travel the length of the working face on the cylindrical projection J, and during this movement its action is to assist in expelling the exhaust or spent gases from the cylinder. The valve can be timed to leave the working face of the cylindrical projection and close the first or exhaust passage C in the cavity of the valve casing at one and the same time or otherwise as desired. In actual practice Mr. James has found that it is not essential in small fast-running engines for the auxiliary valve to entirely close the exhaust port or passage before opening the port or passage for the combustible mixture to enter the cylinder, and the illustration indicates such an arrangement. The auxiliary valve when moved into position to close the port or passage remains in that position until the supply of mixture has to be cut off in the ordinary routine of working.

MODERN GEARING.*

BY H. HUBERT THORNE, WH.EX., A.M.I.MECH.E.

THE subject of gearing is one which has not received the serious consideration of many engineers, partly because of the belief that all gears are inefficient, and partly because a very considerable amount of time must be given if the subject is to be mastered. Probably we have all set out tooth forms during our engineering studies, and consequently we know that the involute possesses advantages over the cycloidal tooth for general use; and that when it is used the centres of a gear can be varied to some extent and still the gear will mesh properly; all that happens when the centres are extended is that the pitch point is moved nearer to the outside of the teeth, the pitches are correspondingly increased, and the pressure angle is also increased. This is a very useful property of the involute, and to-day this form is almost universally used, and so we shall, when speaking of gears in this paper, be considering only involute gears.

The introduction of high-speed motors and the general speeding up of machinery introduced new problems to the engineer; and he set about to find a gear which would run at a high velocity without undue noise and vibration, and one which would give a fairly high ratio of reduction in a single pair of gears. Straight-cut gears did not meet the conditions, as the least number of teeth in the pinion to produce a satisfactory drive having proved to be as high as 15, and according to some authorities 18, a high ratio became impracticable, and even with moderate velocities straight-cut gears of any size were found to be noisy. Two ways of getting over the difficulty presented themselves, one by using pinions of special materials which would not create noise when running with metal wheels, and one by altering the form of the teeth. The former method was adopted for many drives, and pinions of raw hide, compressed paper, compressed linen, fibre, &c., have all been tried, but, on account of the large diameters necessary to accommodate rivets between the bottoms of the teeth and the bore, the wheels became unduly large and heavy, and the ratios obtainable only small. The latter method has also been largely adopted, particularly within the last decade, and has resulted in the development of two distinct forms of gearing, the first worm gearing, and the second double helical gearing.

Worm Gearing.—Worm gearing is quiet in operation, and can be made with ratios as high or even higher than 100:1, but owing to the fact that the rolling action of the correct spur gear gives place to a rolling and rubbing action between the worm and the wheel, the speed of the worm must not exceed comparatively low limits, determined by the conditions under which it has to work, and, further, the efficiency goes down as the ratio increases, and a high ratio worm gear is not by any means an efficient mechanism. The reasonable adoption of worm gears is consequently restricted to comparatively small powers, speeds, and ratios. One case for which worm gear has proved eminently satisfactory is that of small ratio gears for automobiles, where the gears are generally only required with a ratio of 3 or 4:1 and the diameters of the worms are such that the pitch line velocity is not high. For such gears, having both shafts mounted in ball bearings, efficiencies of 95 per cent. are readily obtainable.

Double Helical Gearing.—For high powers and speeds some other form of gear must be looked for than worm gears. To obtain smooth action, Dr. Hooke, who noticed that small pitch gears generally ran more smoothly than coarse pitch gears, but that the strength of the former was correspondingly less than that of the latter, introduced by way of compromise the stepped tooth, which consisted of a number of sections of a spur gear of comparatively fine pitch placed side by side, the teeth of each section being stepped forward a definite amount in relation to the next section, the whole then being made into one gear. By making these sections very thin and the steps very small in relation to the pitch, what is known as a single helical gear results. This type of gear has been used for many purposes, but possesses the great disadvantage that end thrust is set up along the shafts (a disadvantage also inherent in worm gears), and to overcome this two single helical gears of opposite hands were riveted or bolted together, thus forming the double helical gear. This type of gear, which is not now built up from two single helicals but cut direct from the solid blank, is often manufactured with a ratio of 25:1 in a single reduction. It also possesses other advantages over the straight-cut spur gear, and it will perhaps be as well to examine these here.

With straight-cut gears the maximum bending stress on the driving tooth occurs when it just disengages from the driven tooth. As the tooth is straight, this stress is equal along its whole length. With double helical gears this

FIG. 1.

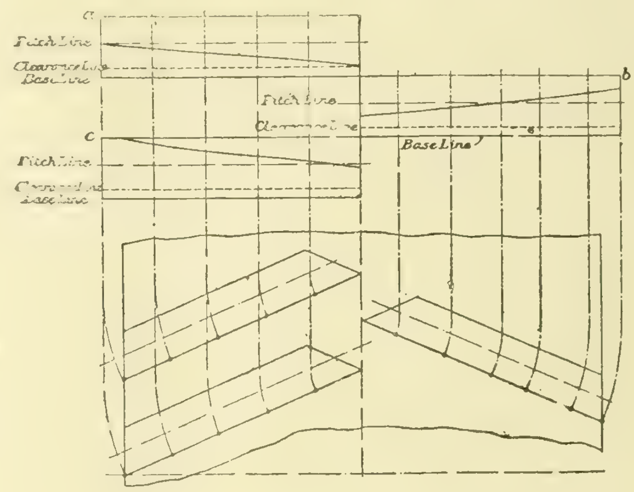


FIG. 2.

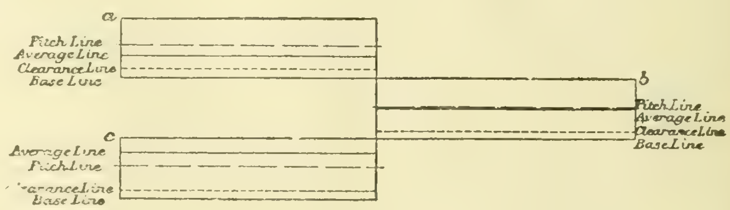


FIG. 3.

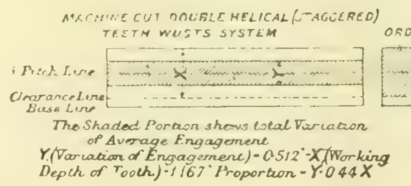


FIG. 4.

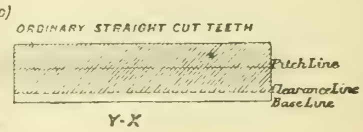


FIG. 5.

maximum stress is only at a point, and not along the whole length of a tooth, the stress varying between the maximum and the minimum along the length. This is clearly seen in Figs. 1 and 2, which show the development of three teeth of the rim of a staggered tooth double helical gear. The elevation shows the lines in contact when the centre of the tooth "b" is in engagement at its pitch line. Fig. 3 shows the average engagement along each of the teeth, and Fig. 4 the total variation of average engagement. Fig. 5 on the other hand, shows the variations of actual engagement along the whole length of a straight tooth. By comparison of Figs. 4 and 5, it will be seen that the variation of stress on the teeth is very much less with the double helical than with the straight tooth, and consequently the former is the stronger.

To obtain really smooth running, it is essential that there shall be rolling contact only, and no rubbing contact. If a 12-tooth standard B & S spur pinion is set out, it will readily be seen that as the line of pressure only reaches a very short distance below the pitch line, the rolling contact must

* Abstract of paper read before the Junior Institution of Engineers, January 1914.

cease some considerable distance from the root of the teeth. As all points of rolling contact must lie along the line of pressure for an involute tooth, obviously all points below this are in sliding contact and not rolling. The exponents of the Stubb tooth endeavoured to get over this difficulty by increasing the pressure angle and decreasing the depth of the tooth, and no doubt such a tooth offers advantages in this particular direction; but, as by such a course the arc of contact is often materially decreased, the engagement conditions become worse, and in many cases the gear proves, if anything, more noisy than if designed to standard dimensions. With double helical gears, on the other hand, the average engagement is spread over an area, the limits of which are comparatively near the pitch line, as seen in Fig. 4, the action becomes more nearly a pure rolling one, and the rubbing action, which must produce wear, is reduced to a minimum.

With spur gears, particularly when the pinion has only a few teeth, a distinct knock is noticeable as the load is repeatedly applied along the whole length of the tips of the teeth, whereas, with double helical gears, however small the number of teeth in the pinion, the engagement at the top of the tooth can only occur at a particular point or points of the face at any one time, the average engagement being always near to the pitch line. In this connection, it must be borne in mind that however wide the face of a spur gear is made, the number of teeth in engagement cannot be altered, but with double helical gears, by increasing the face width, the load is spread over a greater number of teeth. Owing to the elimination of most of the losses due to sliding friction, practically the whole power put in is transmitted through the gear, and from actual tests it was ascertained that with a ratio of 20 : 1 in a single train the efficiency was 98½ per cent. Many double helical gears are now running at ratios of 25 : 1 and over, the only limiting factors being the diameter at the root of the pinion teeth, necessary to resist torsion and bending, the capacity of the machine on which the wheel is to be cut, and the space available; the diameter of the pinion is only limited by the necessary root diameter, because, as previously stated, by suitably increasing the face width of the pinion, any desired number of teeth will be in engagement at one time.

Having now determined that for high-speed drives double helical gears offer great advantages over straight-cut gears, it will, perhaps, be as well to consider more particularly the design and manufacture of double helical gears. Two distinct forms of tooth have now been introduced, known respectively as the "continuous tooth" and the "staggered tooth." The former is manufactured by a number of firms in this country, and patents for the latter are held by Messrs. The Power Plant Company, Ltd., of West Drayton, Middlesex. These two types differ not only in form, but in process of manufacture. Straight-cut gears are produced by several different processes: (1) Milling by means of formed disc cutters or by end mills. (2) Planing by using a shaped former to produce the required tooth shape. (3) Generation by means of tool taking the form of a pinion. (4) Generation by means of hobs having a rack section.

The first of these processes is not applicable to double helical gears with teeth cut from the solid, because of the interference of the disc cutter at the apex or centre of the gear, but continuous double helical teeth are generally produced by means of milling cutters of the end mill variety, these cutters revolving at a suitable speed, and passing right across the face of the gear, the gear itself being revolved backwards and forwards to produce the necessary double helix. The third process mentioned above is now receiving consideration, and patents have been obtained by Mr. William E. Sykes, covering this process. The fourth method, namely, that of generation by means of hobs, is adopted in the production of the staggered tooth double helical gear. In considering these different processes and the results achieved by them, the question naturally arises as to which can be considered to produce the best gears. As the end milling and hobbing processes are the only two which have as yet been thoroughly developed, we will confine ourselves to these.

Continuous Teeth.—The method of manufacturing these is necessarily slow, on account of the comparatively small cutters which have to be used; the cutters [illegible] of end mill form, cannot be reground without [illegible] shape. As the tooth shapes of pinion and wheel to be cut for one set of gear usually vary widely, it is necessary to use different shaped end mills to produce these. It is also necessary to accurately determine the correct section of the tooth to be cut in a plane normal to the helix. [illegible] matter of some difficulty, and even after the shapes have been determined it is not the easiest thing to correctly manufacture the gauges and end mills to suit these shapes, the manufacture being entirely dependent upon the [illegible] of the tool maker. These facts, together with the necessity, particularly observable in the case of large steel gears, of replacing the end mills from time to time, while the [illegible] being cut, render the accurate production of [illegible] a matter of difficulty. Further, on account of the fact that the end mills at the point corresponding to the pitch line of the gear can only be one-half the circular pitch in diameter, this process cannot be satisfactorily used for the production of small pitch gears. With a pitch of 1in. the cutter is only ½in. diam., and much below this it is obvious one cannot go in the size of an end mill to produce accurate gears. Another drawback to the process is that step-by-step division, with its inherent difficulties, must be used.

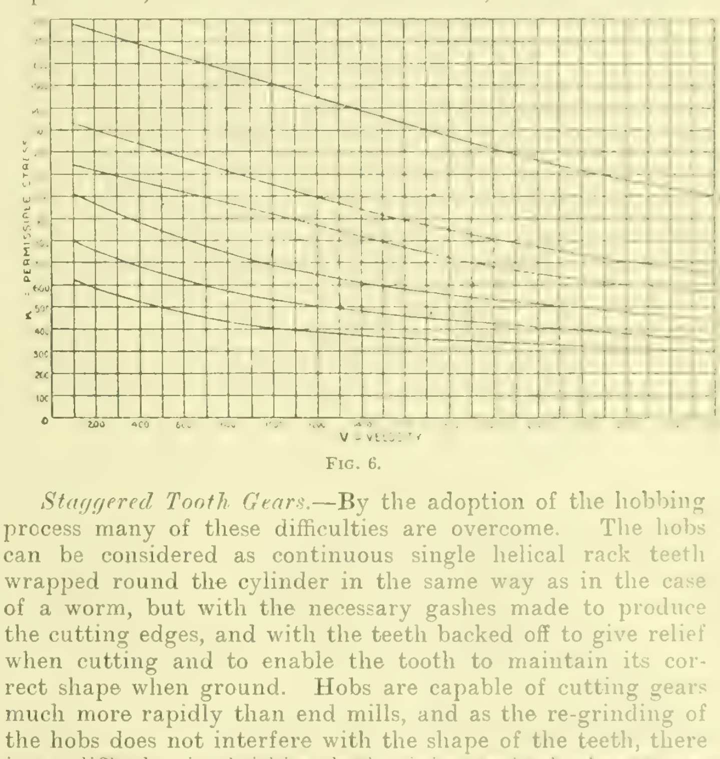


FIG. 6.

Staggered Tooth Gears.—By the adoption of the hobbing process many of these difficulties are overcome. The hobs can be considered as continuous single helical rack teeth wrapped round the cylinder in the same way as in the case of a worm, but with the necessary gashes made to produce the cutting edges, and with the teeth backed off to give relief when cutting and to enable the tooth to maintain its correct shape when ground. Hobs are capable of cutting gears much more rapidly than end mills, and as the re-grinding of the hobs does not interfere with the shape of the teeth, there is no difficulty in finishing both pinion and wheel [illegible] tool, and, further, as the section of the hob is really a rack with straight sides formed to the desired pressure angle, a hob can be produced with extreme accuracy, there being no curved shapes to determine. For small pitches down to 10 d.p., or even 12 d.p., hobs can be produced as readily as for pitches of 1in. and over, and, as the cutting process is a continuous one, step-by-step division is dispensed with.

There then only remains the question of strength. It is claimed by manufacturers who only make the continuous tooth that it is necessarily stronger on account of the continuous centre portion. If gears were designed for strength only, this would be an admissible argument, but it is a well-known fact that for high-speed gears it is useless to determine the sizes merely from the point of view of strength, as, if this is done, very rapid wear will result. Such gears must be designed with a view primarily to wear; and, if this is done, it is safe to say that the gears will be amply strong for their duty, whether they are of the continuous or the staggered tooth type. In fact, it will be found in [illegible] cases where gears have been properly designed for wear, that the factor of safety lies between 10 and 20. Whilst the continuous tooth may be slightly stronger than the staggered

tooth, it must not be forgotten that this extra strength itself produces certain disadvantages. If the teeth of a gear be considered as cantilevers, it will be seen that in order to offer even resistance to bending, the section must be the same throughout. With the staggered tooth gear this is so, but with the continuous tooth the centre portion offers far greater resistance than the outside portions, and the difference in resistance may result in uneven wear of the tooth.

Designing Double Helical Gears.—Forged steel pinions containing about ·4 per cent. carbon and cast-iron wheels are to be recommended, but, where the tooth pressure is heavy or the gear subject to shocks, cast-steel wheels may be used, and it may be necessary, particularly when the velocities are high, to resort to alloyed steel pinions, but these cases should only be dealt with by the specialist. The following factors should be borne in mind. Small diameter gears will, if properly designed, run more silently than larger ones on account of the lower velocities, and the number of teeth in engagement can always be increased by widening the faces of double helical gears. Both pinion and wheels should be supported on either side close up to the teeth wherever possible by bearings of ample dimensions and rigid construction. The size of the pinion is generally, when centres are fixed, determined by the necessary pinion shaft diameter. This diameter must be sufficient to resist bending and tortional strains.

In the case of sleeve pinions enough metal must be allowed between the top of the key and the root of the teeth to ensure sufficient support for the teeth. Where pinions are overhung on motor shafts it is generally safe to take, as a rough rule, the pitch line diameter at least twice the diameter of the motor shaft. Where pinions are cut solid on their shafts the root diameter of the teeth need only be sufficiently larger than the diameter of the shaft to ensure the hobs running out without cutting the shaft. The questions of bending and torsion come in more particularly in the case of turbine and other very high velocity gears. Where the powers to be transmitted are high it is often necessary, in order to keep the diameters, and consequently the velocities, within reasonable limits, to make the faces of such width that a third bearing must be introduced in the centre of the pinion shaft. In such cases the torsion of the shaft may cause some slight displacement of the teeth of the two halves of the pinion in relation to one another. Endeavours have been made to overcome this in different ways.

As the minimum diameter of the pinion is only fixed by the shaft diameter necessary, and, as any required engagement conditions can be provided by increasing the face of the gear, it follows that comparatively fine pitches can be used. With continuous teeth it is usual to make the angle of the helix 45°, *i.e.*, the included angle 90°, and the face at least four pitches wide. With the staggered tooth gears the angle usually employed is 67°, *i.e.*, the included angle 134°, and the pressure angle 20°, the face at least five, and preferably six times the pitch, or even more. By the introduction of these fine pitch small diameter pinions it follows that very much larger ratios can be used for the same diameter wheel.

Emphasis has already been laid on the fact that gears should be dimensioned primarily with a view to wear, and in this connection it should be remembered that for a given pitch diameter and pressure angle, whatever the pitch, the involute curve to which the tooth conforms is the same. Consequently, with any particular pair of gears, the two curves in contact are unchanged, whatever the pitch may be. It is fairly obvious that, if a load is to be sustained by two curved surfaces in contact, the larger the diameter of these curves at the point of contact the better it is. When, however, the diameters of the gears are reduced, the radii of the curvature of those portions of the involute forming the face of the teeth are also reduced, and consequently the engagement conditions are rendered somwhat worse. This fact is generally taken into account by designers of double helical gears, particularly when they are dealing with very small diameter gears. In the established formula, a varying factor is used for permissible stress, and curves have been plotted giving the values for different velocities, these curves being based on certain definite diameters. Fig. 6 gives these curves for different materials, and the curves themselves can be taken as sufficiently accurate for gears of ordinary sizes, but the width of face should be increased somewhat for very small gears. The exact amount of increase necessary has been determined, but there are no data on the subject at present available for publication. The formula generally used for staggered tooth gears is as under:—

Where:—

H.P. = Horse-power.
P = Tooth pressure in pounds.
K = Admissible stress (see curve).
D = Pitch circle diameter in inches.
p = Pitch in inches.
W = Total width of face in inches.
V = Velocity of pitch circle in feet per minute.
N = Revolutions per minute.

Then $$V = \pi \times \frac{D}{12} \times N.$$

$$P = \frac{H.P. \times 33000}{V.} = \frac{p \times W \times K}{2.}$$

And for ratios up to 6 : 1:—

$$W = 6\,p \text{ (Normal width).}$$

$$p = \sqrt{\frac{P}{3\,K.}}$$

And for ratios above 6 : 1:—

$W = R \times p$, where R = ratio to 1 up to the maximum of $W = 10\,p$.

$$P = \sqrt{\frac{2{\cdot}5\ P.}{R \times K}}$$

Example 1.—Required a gear to transmit 85 h.p. and reduce from 680 : 115 revs. per minute, and work at about 24in. centres; pinion of forged steel, wheel of cast iron.

Then ratio = 5·9 : 1.

Approximate diameters = 7in. × 41in.

$$V = \frac{\pi \times 7 \times 680}{12} = 240 \text{ approx.}$$

$$P = \frac{85 \times 33000}{1240} = 2300 \text{ approx.}$$

$$p = \sqrt{\frac{2300}{3 \times 500}} = 1{\cdot}24 = 2\tfrac{1}{2} \text{ D.P.}$$

The gears required are therefore:—

F.S. 17 }
C.I. 101 } teeth $2\frac{1}{2}$ D.P. × 8in. face × 23·6in. centres.

Mention has already been made of the sizes of shafts and the stiffness of bearing supports. Where the velocities are over 1,500ft. per minute, it is always advisable to totally enclose the gears and run them in oil, and when the velocities are very high, say 3,000ft. per minute and over, the oil should be squirted under pressure along the face of the gear near the line of engagement, and forced lubrication should be provided for the bearings.

Explosion of a Compressed-gas Cylinder on the "Mauretania."—On Monday night last a disastrous explosion occurred on board the Cunard liner "Mauretania." The vessel was lying in Canada Dry Dock undergoing engine repairs, which included the insertion of a number of blades in the high-pressure turbines. For this purpose an autogenous welding plant was being used, and it is stated that, without the slightest warning, a cylinder of compressed gas in connection with the plant burst, with terrible results to about a dozen men who were engaged in the room at the time, three being blown to pieces, and eight others injured, some of them so terribly that it is doubtful if they will survive. The cause of the explosion has not, at the moment of writing, been ascertained, but will doubtless be enquired into at the inquest.

AULD'S SAFETY VALVE.

WE illustrate herewith a design of safety valve, the invention of David Auld & Sons, Ltd., Whitevale Foundry, Rochester Street, Glasgow, of the class which are adapted to allow over-pressure steam to escape from the full area of the main valve or nearly so, the main valves being opened by the steam pressure acting on one side of a piston secured to the main valve when the pressure on the other side of the piston, which maintains the valve in the closed position, is relieved by auxiliary valve opening by the action of the over pressure on a piston secured to the auxiliary valve. In this design only one cylinder is employed for the two pistons which are connected to the main valves, and are fitted to move simultaneously in opposite directions, while a cage arrangement is adapted to hold the moving parts in position while permitting them to be easily withdrawn when desired for inspection or repair.

Referring to the illustrations, Fig. 1 is a front elevation of a double safety valve, Fig. 2 is a corresponding side elevation partly in section, and Fig. 3 is a front sectional elevation. The inlet A and the outlet B are formed by the casing of the valve, and are separated by that portion of the casing forming the cylinder C. Within this cylinder are fitted the pistons D and E, which are formed in one with the two main valves F and G. A guide pin is screwed into the piston D, and enters an eye in the piston E to act as a guide and steady the motion of the pistons as they move to and from one another. The seat for the valve F is formed on the casing and the seat for the valve G is formed on the cage device H. Regulating springs are fitted round the spindles of the main valves. The auxiliary or regulating valve consists of a valve J connected by a spindle to a piston K below which is always open to the steam pressure through the duct L leading from the boiler to the chamber M. The valve spindle is hollow above the valve and is formed with a piston N to balance the valve J. A spring is provided for controlling the action of the valve J. The steam is led from the space between the pistons D and E by the port O and duct P to a chamber Q below the regulating valve J.

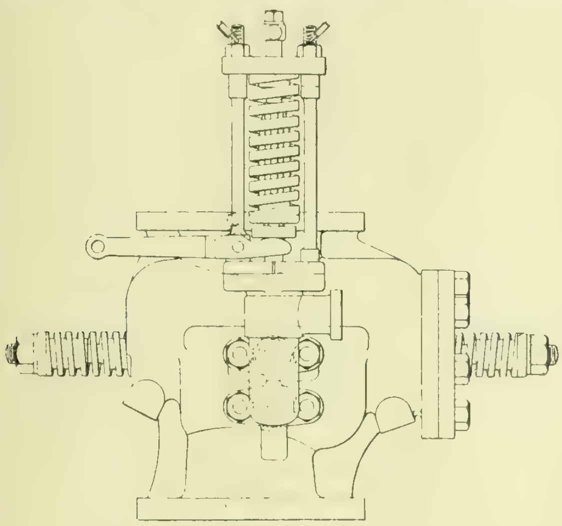


FIG. 1.

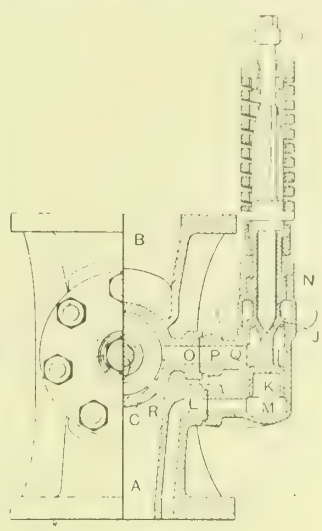


FIG. 2.

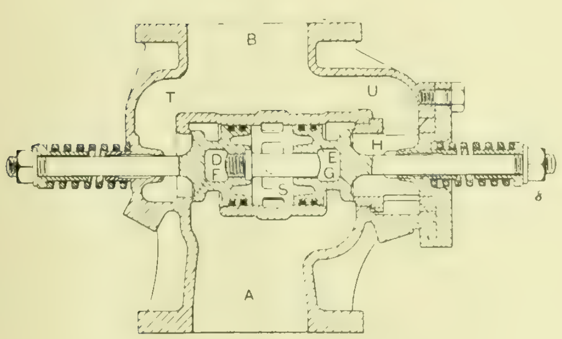


FIG. 3.—AULD'S SAFETY VALVE.

The action of the valves is as follows: Fluid pressure enters the main valve casing by inlet branch A and flows along the ports or ducts R into the space between the main valves F and G and main pistons D and E. The fluid pressure also leaks past the main piston into the space S in main cylinder C, thereby acting on the opposite side of the main pistons and holding the main valves tightly on to their seats. The fluid pressure contained in the space S between main pistons passes through the port O and duct P to the chamber Q under the regulating valve J. The inlet pressure also passes by the port or duct L to the chamber M and acts on the underside of the piston K connected to the regulating valve J. This regulating valve is loaded to a predetermined pressure by means of the spring shown, and immediately the inlet pressure tends to exceed this amount the regulating valve J is forced off its seat by the pressure on the piston K and under the valve overcoming the force exerted by the spring. On the regulating valve J opening the pressure contained in the space S between the main pistons is exhausted through the port O and duct P and the pressure is thereby reduced considerably.

Although the pressure under regulating valve J is altered by this action the adjustment of the regulating valve is kept constant by the inlet pressure constantly acting under the piston K. The pressure contained in the space S between the main pistons being considerably reduced, the initial pressure acting on the annular part round the outside of the main pistons overcomes the pressure holding the main valves on their seats, thereby opening the main valves. Fluid pressure now flows through the valve seats into the outlet branch B from the valve F by the duct T, and from the valve G through openings in the cage device H and duct U. When all the surplus pressure has been discharged the spring closes the regulating valve J, shutting off the escape of pressure from the space S between the main pistons, wherein the initial pressure now accumulates and closes the main valves by acting on the main pistons, as already described. The same cycle of operations is repeated so long as the inlet pressure tends to rise above that to which the regulating valve is set. When the regulating valve J is opened by means of the hand easing gear provided, the main valves will be opened in the same manner as when the regulating valve J automatically opens due to over pressure.

LOCOMOTIVE BOILERS.

IN a paper on "Locomotive Boilers," read before the Northampton College Engineering Society on January 16th, Mr. W. S. Salter said that, like many essential parts in a locomotive, the boiler must be designed to work in a confined space. Should a larger boiler be required, the enlargement must be done carefully, so as not to disturb the standards of the loading gauge and axle loads. The workmanship and method of manufacture had been greatly improved in railway shops, owing to the introduction of modern machines. The boiler design was based on the size of the cylinders. The grate area was also designed in a certain proportion to cylinder volume. For a usual type of passenger engine the heating surface would be about 1,100 sq. ft., firebox heating surface 120 sq. ft., and grate area 18 sq. ft. The 1,100 sq. ft. would be made up of, perhaps, 220 tubes, 2in. diam., and from 9ft. to 10ft. long. A number of slides were shown illustrating the construction of the boiler. The barrel comprised two or three plates with longitudinal butt joints. The circumferential joints were usually single-riveted lap joints. The joints between the barrel and throat plate and wrapper and barrel varied according to the builder. The inside firebox was supported by the foundation ring at the bottom, and the roof was supported by either bridge or sling stays. The sides were stayed by copper stays screwed through the casing and into the firebox and riveted either end or both. With

regard to the material used for boilers, it was, he observed, certain that Low Moor iron would stand the wear and tear of running better than practically any steel, but steel came into general use due to its price and strength. The copper used for the inside was specified as "best copper" because pure copper was too soft and liable to burn away. One of the greatest troubles with boilers was grooving, and a constant watch must always be kept for this. Bridge stays, although heavy and clumsy, had the advantage over vertical stays that while the firebox crown was supported there was always space for the inner firebox to move up with expansion. The Belpaire firebox could use vertical stays owing to the flat casing and flat crown, but even where the casing became stiffer the vertical stays were fitted with an expansion bracket. A number of "patent" copper stays had been introduced with special means of showing failures, but most English railways used the plain stay and preferred to examine each stay. The tubes were usually made of steel, except in certain parts where iron was used—due to the difference of the water.

EFFECT OF PRESS WORK ON THE SEASON-CRACKING OF BRASS.

THE season-cracking of brass is almost invariably found in instances where the brass has been drawn or otherwise worked. It does not appear to have been found in cast or similar articles, and while it is now and then located in annealed brass goods, such cracks as may appear are usually a case of crystallisation, and are brought about by external influences such as compounds containing ammonia or similar agents. This, however, is comparatively rare, and by far the greater number of instances of the cracking of brass is on drawn brass, and are season-cracks, pure and simple. Season-cracks do not appear to be confined to yellow brass alone, so that one cannot say, therefore, that the brass itself is alone subject to it, but other metals as well occasionally show it. Soft metals, such as copper, soft bronze, &c., are not subject to it, but the hard metals, which have been drawn, will usually crack under the right conditions. Aluminium-bronze, which hardens rapidly when rolled or drawn, is subject to it, and as this alloy is of a different nature than brass, it is apparent that zinc is not the cause of the cracking.

Season-cracks are caused by internal strains in the brass. This fact is the reason why the cracks appear in drawn brass goods. Those which are annealed do not show it. Neither do those which have been properly drawn. With those which have been drawn in a press in an imperfect manner, strains are set up which finally result in actually pulling the metal apart. Let the matter be analysed more thoroughly. A thick seamless drawn brass tube is a good example of an object in which strains can be set up. When this is drawn through a die in a manner so that only the outside layer is worked, and it is drawn quite hard so that there is left little elongation and reduction of area, the inside is left comparatively soft and the outside drawn hard so that there is always a tendency for the outside layer of metal to pull away from the inside. If the tube is now annealed, the strain will frequently cause the tube to crack and open up at the end like a flower, bending outwards. The strain on the outside pulls the metal from the inside, causing an outward bending with the flower-like appearance. On the other hand, if the tube is not annealed, but is left in its hard-drawn condition, it will probably crack in the same manner in time. How long a time will depend upon the condition of drawing, but if it does occur the end of the tube may have the appearance identical with that of the tube which has been annealed. Fire-cracks and season-cracks are, therefore, produced by the same cause, viz., internal strains in the brass.

In the case of sheet brass that has been drawn in the press, the effect is the same as that of the previously-mentioned tube. Strains are set up in the brass which, under the influence of time, cause the metal to be pulled apart. In one instance a piece of a shell of drawn brass was badly season-cracked. This was of ordinary yellow brass sheet and had cracked only after a lapse of a number of years. At first there was no indication of cracking in the shell, but after about a year small cracks could be seen, and these finally opened out. Sheet metal is drawn in a press by means of a punch and die. The die, of course, is the shape of the outside of the shell while the punch determines that of the inside. It seems a very simple matter to form a cylindrical shell, and so it is, but the difference between good and poor press work will determine whether the shell will season-crack or not. If the brass is simply formed into shape by the punch and die and the metal is not worked or stretched in any way, it will be pretty likely that it will season-crack, as there will be strains set up in the metal which will cause an uneven tension to exist, and that will result in the ultimate tearing apart of the shell. On the other hand, if the shell is drawn so that the metal is actually stretched even a slight amount, season-cracking will be prevented. In connection with this important part of the drawing of brass shells, the following observations on the making of objects of brass by means of the press were published in "The Brass World," July, 1906, page 237, the author of which was Edgar P. Webster, an expert in the drawing of metals. In connection with the season-cracking of drawn brass shells, he said:

"A large quantity of drawn brass shells were made from sheet in a drawing press. The relative shape of the die and force was such that the brass was not stretched in any way. The shell was formed and that was all. When the shells were finished, they had small wrinkles or corrugations on the surface; not enough to be conspicuous, however, but nevertheless sufficient to indicate that the metal had not been stretched at all. The shells were placed in barrels and set one side, and within a short time all of them had split open. After giving the matter much consideration, it was decided to shrink the die a small amount so that the metal in the shell would actually be stretched a small amount, so that it would be drawn and not 'formed.' This was done, and the result was that all the shells came out right and without the formation of any season-cracks. I shall not attempt to comment on the theory of this method of preventing the season-cracking of drawn brass shells, as it seems difficult to explain. The fact remains, however, that if the sheet brass is drawn in a press in such a manner that the metal is only formed into shape and not stretched at all, season-cracking will undoubtedly take place. The method of preventing season-cracks is to make the die so that the metal will be stretched a small amount. If forming has taken place and the metal has not been stretched the surface will usually have wrinkles. On the other hand, if the metal has been stretched, it will have a smooth appearance. I do not know of any better expression than to say that the metal must be 'ironed out.' The object is to stretch the brass to a slight degree."—"The Brass World."

The Cost of Rubber.—Some interesting figures relating to the rubber industry of the Federated Malay States are furnished in the annual report of the Chief Secretary for 1912. This states that the area opened in the Protectorate for rubber that year was 54,105 acres, as compared with 107,200 acres in 1911. There were 703 estates working. The Director of Agriculture finds it difficult to arrive at any definite conclusion as to the cost of production from the returns furnished by estates, but he is convinced that with a sound system of accounts rubber is being produced in Malaya and placed on the market at from 1s. to 1s. 2d. per pound, and he has no doubt that, with the increasing age of the trees, thinning out, and the consequent reduction in the cost of tapping for the same amount of rubber, these figures will be reduced. It is, however, considered advisable to warn planters that they must be prepared to face synthetic rubber as a competitor, a number of chemists in England and Germany being engaged in working out this problem, and he observes that because the first announcement was premature, the attitude that there is nothing to be feared is strongly to be deprecated. Mr. Eaton, the chemist of the department, during a visit to Germany, was able to obtain samples of synthetic rubber, which might be described as slightly inferior plantation crêpe. The cost, he was informed, was about 2s. a pound. In his opinion, there was no need to fear the competition of synthetic rubber for several years, when plantation rubber can be put on the market by well-managed estates at 1s. a pound. It is announced that the amount of capital invested in rubber growing in the Federated Malay States is £40,000,000 sterling.

POWER PRODUCTION IN THE UNITED KINGDOM.*

BY EDWARD G. HILLER, M.I.C.E., M.I.M.E.

IN this country the utilisation of the natural sources of energy on a large scale dates from about the middle of the eighteenth century when the improvements in the steam engine made by Newcomen, Smeaton, and Watts placed at the service of industry for the first time a practical producer of mechanical energy from coal. Since that period developments have proceeded rapidly, and in all departments of the modern social organism the utilisation of the natural sources of energy is found more or less developed. In many industries hand working has been replaced by power-driven factories; transport of all kinds is now carried on by power-driven appliances such as steamboats, locomotives, motor-cars and motor-wagons. In every direction the endeavour of man to obtain an easier way of living is finding a more or less partial solution in the adoption of the utilisation of some natural source of energy.

The power production of the country may broadly be looked at much as the performance of a single engine is considered. In the United Kingdom the principal source of mechanical energy lies in the coal. A certain amount of this coal is produced and utilised in power production either by steam boilers and steam engines, steam turbines, gas producers, gas engines, and the like; and the total efficiency of the combined machine as regards the coal which is utilised and the power which is given out by the whole power equipment of the country might be considered from the point of view of efficiency, just as in one single factory an efficiency factor might be determined by the coal given into the boiler-house, and the energy which is given out at the engine crank shaft. Similar questions as those which apply to a single engine may be applied to the whole of the power of the United Kingdom. How does it develop its power? How much power is developed and with what efficiency? What are the relative results of the different kinds of power producers as regards economy, efficiency, and reliability? A further step might be taken by comparing the efficiency of this particular machine with that of other power plants on a large scale, such as the power production of the United States of America, France, or Germany.

A critical comparison of the results obtained in different ways might be useful in indicating in which directions improvements are to be expected. A similar comparison of the rational basis of the various differences which are to be observed in power plant in different countries ought also to be helpful. Some countries show great development in one sort of power; others seem to lag behind. A reply to the question as to the origin of the difference would indicate whether the lagging behind was apparent or real; whether, in fact, the country which lagged behind might be producing its power at a greater expenditure of coal, but at a less total expenditure having regard to the whole of the expenses involved in the production of the power.

Again, in different parts of the United Kingdom the state of development of power-producing machinery varies considerably. In some districts the power-producing machinery in operation is of the highest development; in other parts apparently methods of power production have stood still for a number of years. A comparison of this kind might lead to serviceable action if the industries of the United Kingdom were under one management. The industrial kingdom, however, is under a multiplicity of individual managements, and their shortcomings only become evident under the pressure of competition or by the advice and information given by consultants, insurance companies, and other power doctors. The latest and newest in power production is not immediately brought before the notice of power users, but the realisation of their inefficiency is slow and often indirect; consequently progress in economy and efficiency of power production is irregular and often delayed. In some industries and districts conditions have called for a greater degree of economy; in other cases profits have been made without high efficiency in power development, or enterprise has lagged behind in the district, and old-fashioned and wasteful methods consequently persist.

* Paper read before the Manchester Association of Engineers, January 24th, 1914.

In a place like the United Kingdom where so much is left to individual development, the efficiency of power production shows great variety of attainment. To completely depict the present condition of the United Kingdom in the matter of power development obviously involves the building up of details and particulars of a large mass of general statistics, and at an early stage it became evident to the author that it would be necessary for him to place such limits on the scope of this enquiry as would enable it to be dealt with in the time at his disposal.

A large number of statistics bearing on this subject have been collected and issued by the Government of this country, and the Final Report of the First Census of Production of the United Kingdom (1907) includes much information. In some directions, however, definite information is lacking. The picture, therefore, which the author is attempting to give must in much of the detail be lacking in definition, but it is hoped that the general view conveyed will be of interest, and that some of the comparisons and results of experience will be of service.

This review is intended to cover the field of mechanical power production on land for the driving of factories and works. It includes: Fixed motive power for factories, mines, and the like; fixed boilers, steam engines, steam turbines, and the like; fixed gas engines and oil engines. It does not include any close consideration of railway locomotives, motor-cars, or steamboats. In the fixed boilers are included those at power stations developing electricity and the like. Electricity is considered not as a motive power, but, for the present purpose, as a means of transmitting motive power.

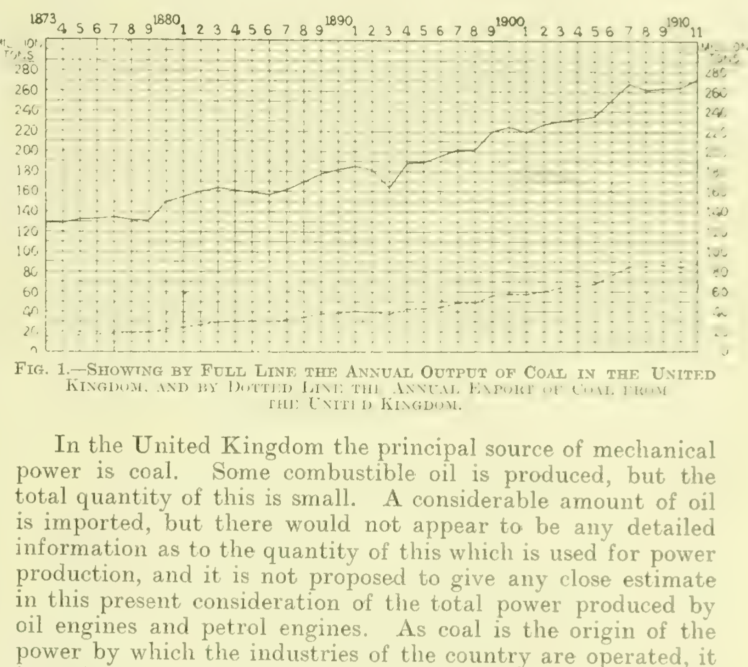


FIG. 1.—SHOWING BY FULL LINE THE ANNUAL OUTPUT OF COAL IN THE UNITED KINGDOM, AND BY DOTTED LINE THE ANNUAL EXPORT OF COAL FROM THE UNITED KINGDOM.

In the United Kingdom the principal source of mechanical power is coal. Some combustible oil is produced, but the total quantity of this is small. A considerable amount of oil is imported, but there would not appear to be any detailed information as to the quantity of this which is used for power production, and it is not proposed to give any close estimate in this present consideration of the total power produced by oil engines and petrol engines. As coal is the origin of the power by which the industries of the country are operated, it is to be regarded as an essential element of the prosperity of the country. As compared with water power, coal has one serious disadvantage. Coal is used up and disappears; water power is renewed. The water power of Norway, for instance, is being continuously replenished by the action of the sun in evaporating water and depositing snow on the mountains, but the coal supply of our country is being used up without any present prospect of any new source of energy to replace it. From this point of view there is ample justification for the attention which has been given to this store of energy by Royal Commissions, and for the careful consideration of all reasonable means of conserving the store of energy and economising its use.

Fig. 1 shows the amount of the coal produced in the United Kingdom, and also the amount exported for the years referred to. The upper full line representing the total output shows the continuous but fluctuating increase which marks the development of the coal industry, the demand increasing both for home consumption and export. The home consumption is represented by the distance between the top full line and the lower dotted line. In the earliest year shown, 1873, the home consumption was about 113 million tons; in the latest year shown, 1911, it was about 185 million tons, an increase of over 60 per cent. The dotted export line,

however, shows a tendency to still more rapid increase, the figures being about 16 million tons for the earliest year, 1873, and for the last year, 1911, 87 million tons, which is between five and six times that of the earlier year. In fact, this particular part of the coal consumption is growing so rapidly

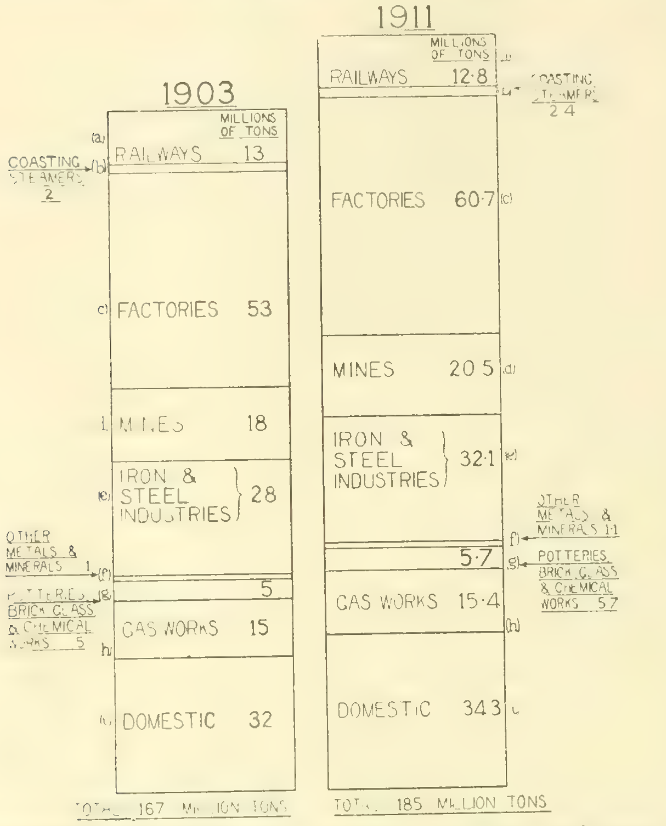


FIG. 2.—APPROXIMATE SUBDIVISION OF THE USES TO WHICH THE COAL CONSUMED IN THE UNITED KINGDOM IS APPLIED.

that, as was recently stated by a leading authority, the great developments in new collieries seem likely to do little more than keep pace with the increase in exports. It will be seen that the total output of coal from the United Kingdom in the year 1873 was about 129 million tons, and in 1911 it was about 272 million tons, the output during that period having therefore rather more than doubled.

An examination of the figures would indicate that the amount of coal produced which was retained and consumed both for industrial and domestic purposes in the United Kingdom in 1873 was at the rate of 3·5 tons, and in 1911 4·08 tons per head of the population. This is, of course, only a method of representing to the mind in a tangible form something like the rate at which stores of natural energy are being used. The figures of 129 million tons and 272 million tons, in themselves, do not convey any very definite idea of what is going on. The increase in the rate of consumption per head of the population would indicate broadly that these figures are in agreement with common experience, which is that there is a gradual tendency to use more and more the energy derived, directly or indirectly, from coal, in carrying out the industries and the ordinary occupations of the people of this country.

On Fig. 2 is shown an estimate for the years 1903 and 1911 of the approximate sub-division of the uses to which the coal consumed in the United Kingdom is applied. The year 1903 has been taken because that is the year covered by report of the Royal Commission on Coal Supplies, which is the origin of this set of figures. The 1911 figures are the latest available at the time of writing. The figures such as those for railways, coasting steamers, and gasworks are taken from the direct official returns, but the sub-division of the other figures is mainly estimated. It is to be observed that these figures will be affected as from year to year by several factors. The steady increase of population will tend to a steady gradual growth of coal consumption in industry and for domestic purposes. The cyclic fluctuations of trade from year to year will affect the amount used in different industries, and the weather will affect the amount of the purely domestic consumption.

In 1903 the coal consumed on the railways of the United Kingdom was at the rate of 13 million tons, and in 1911 12·8 million tons, showing a slight apparent decrease, although the railways are obviously being used in carrying an increasing population, with a corresponding increase of movement of industrial goods and necessaries of life. These figures indicate broadly that such transport, on the whole, was being done more economically in 1911 than in 1903, so far as fuel consumption is concerned, by the railways. This economy in fuel may not, however, be due to improved methods of directly utilising the energy so much as to economies of administration which the railways have introduced, such as the dropping of unnecessary trains and as far as possible travelling with full trains. The figures suggest that, in one way and another, considerable economies have been possible with existing methods of working with ordinary steam locomotives.

The coal used for coasting steamers is only a relatively small item, but is set down separately because separate official figures are given for it. This is part of the home consumption of coal, and is, of course, subject to the general improvement which is taking place in the utilisation of steam and in fuel economies on board ship. It is not necessary to remind engineers that a continuous force is working in the direction of the adoption of more economic driving methods. It is not the scientific interest in the economy of the utilisation of energy which leads to the adoption of more economical driving, but the power user's realisation of the fact that if he can save coal, he can—other things being equal—make more profit. This is an automatic impulse always tending towards the adoption of those methods which, on the whole, conduce to the desired end.

The proportion of coal consumed under the various headings which is used for steam power will, of course, vary. Probably the greater part of that under the headings of factories and of mines is used for power, and also a large proportion of that under the heading of iron and steel industries; the remainder of the fuel being utilised mainly for the production of heat for manufacturing processes and other

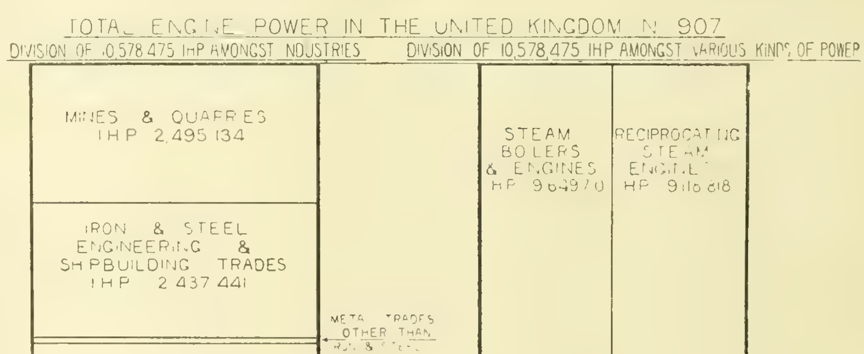


FIG. 3.—DIVISION OF TOTAL ENGINE POWER AMONGST DIFFERENT INDUSTRIES, AND DIFFERENT KINDS OF ENGINES.

objects. In this connection it is to be observed that whatever the future of steam in power production is likely to be, its use for heating and manufacturing processes is continuously expanding at the present time, and there is no sign of the obsolescence of steam as a form of commercial energy.

The estimated figures for the coal consumed in factories were in 1903 53 million tons, 1911 60·7 million tons. This is the largest single heading of the sub-division, and includes the principal classes of power production, also the amount of fuel used in processes of manufacture such as bleaching, dyeing, drying, and the like. On the whole, it is to be observed that no great change in the methods of factory driving has taken place during the period referred to. Textile factories are still mainly driven by steam boilers and engines with a separate power installation at each works, but in later years a large number of industrial establishments, mainly small ones, have found it to their advantage to buy their power rather than to generate it separately. In 1903 the power stations for the production and distribution of electricity were not in so strong a position as at present. In later years their importance has steadily grown, as is shown by the figures of Fig. 3 and Table I. In most cases, as in those of ordinary town supplies of electricity, coal-fired boilers and steam engines or steam turbos are used for the generation of electricity, but in some districts, as on the North-east Coast, much of the energy which was previously thrown to waste is now being utilised in the form of blastfurnace gas engines or exhaust steam turbos, used to produce electricity for sale.

In the power production in factories, changes toward greater economy are slowly and continuously taking place. Competitive movements in trade exercise a continuous pressure in the direction of improvement in method of power production. The question of cost of power is always involved in the cost of the manufactured article to a greater or lesser degree according to the nature of the trade, and it often happens that the costly and ancient methods of producing power are associated with wasteful manufacturing plant, so that the movement for the improvement of the one also affects the other. The use of steam for small independent units of power is probably decreasing, particularly in large towns where gas or electric supply is available, small steam engines for power production being frequently replaced by electric motors or small gas engines, except in those cases where steam is also used for manufacturing purposes. Larger factories show a general advance in economy, the standard plant in the larger textile factories consisting of Lancashire or similar boilers combined with superheaters, fuel economisers, and Corliss or drop valve steam engines. Some few of the larger factories are driven by turbos and some by gas engines, but a number of large factories are driven by electric power from electric stations.

As regards economies generally, it is to be observed that great economies cannot come at once. Old plants must generally work out their time before replacement. A comparison of the cost of modern plant with old plant seldom shows that the savings of the modern plant are sufficiently great to justify financially the pulling out of an old plant which is in good condition. As a rule, the economic changes are effected when old plants are worn out or when new factories are started; consequently, changes in economy of power are slow in taking general effect, and at any period the mass of power producers include: (1) Some old wasteful plants. (2) A large number of middle-aged plants, with moderate economy. (3) A proportion of new plants, with the best economy available up to date.

The first two factors, of course, affect the average of economy, and while therefore the total economy improves, the average economy necessarily is always materially below the best.

The consumption of coal shown at mines of various kinds was: 1903, 18 million tons; 1911, 20·5 million tons.

In the period referred to there had been considerable developments of mining in some districts; thus, the coal mining industry would appear to be pushing east in the Yorkshire and Nottingham district, the tendency being to larger undertakings with more efficient power equipment than was the practice in the past with colliery undertakings. In earlier times one of the districts in which fuel economy reached its highest point was in Cornwall in connection with tin mines in that district. For some years the metalliferous mining of that part of the United Kingdom was a very flourishing industry, and then owing to cheaper foreign production of the metals, the Cornish industry fell away. Between 1903 and 1911, however, a revival of the industry has taken place, steam boilers being used for this to some extent, and also internal-combustion engines.

In past years generally a low economy of fuel was observable in connection with colliery practice generally, the exhaust steam from all engines blowing away and the power being developed about the pits by wasteful small engines for hauling, pumping, and ventilation, either connected by long steam pipes which lost heat by condensation, or provided with independent and somewhat wasteful boilers. In many old coal pits, considerable economy has been effected by installing exhaust or mixed pressure turbines to utilise the exhaust steam, and by putting down central stations, distributing the power electrically and driving the power station by

TABLE I.—*Capacity of engines owned and amount of electricity purchased.*

Group of Trades.	* Gross Value of Output.	Steam Engines: Reciprocating.	Steam Engines: Steam Turbines	Steam Engines: Total Steam Engines	Internal Combustion Engines Gas, Oil, &c.	Water Power	Other Power	Total Capacity of Engines	Electricity purchased ‡
(A) FACTORIES WITH THEIR OWN ENGINES.									
	£000	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	1,000 [illegible]
Mines and Quarries	141,551	2,415,841	3 560	2 419 401	23 191	8,295	44 247	[illegible]	[illegible]
Iron and Steel, Engineering, & Shipbuilding Trades	367 159	2 109,631	69 577	2 179 208	215 252	21 181	21 800	[illegible]	[illegible]
Metal Trades, other than Iron and Steel	90 081	55 612	480	56 092	20 110	7 707		83 909	[illegible]
Textile Trades	295,077	1,873 169	13 665	1,886 834	39 972	51 612	119	[illegible]	[illegible]
Clothing Trades	65 604	46 352	1 727	48 079	35 338	972	417	84 806	[illegible]
Food, Drink and Tobacco Trades	259 744	266 299	3 252	269,551	65 891	12 722	2 007	380 171	[illegible]
Chemical and Allied Trades	72 561	182 456	734	183 190	25 709	4 490	1 381	[illegible]	[illegible]
Paper, Printing, Stationery and Allied Trades	59,077	179 762	3,498	183 260	43 192	11 077	44	[illegible]	[illegible]
Leather, Canvas and India Rubber Trades	31 066	45 613	31	45 644	8 330	870	47	54 891	[illegible]
Timber Trades	38 143	113 187	907	114,094	54 293	5 348	78	173 813	[illegible]
Clay, Stone, Building and Contracting Trades *	74 710	347 647	6 257	353 904	74 875	4 042	163	[illegible]	[illegible]
Miscellaneous Trades	6 215	3 900		3 900	5 274	178	65	9 417	[illegible]
Public Utility Services †	70,447	1 379,376	427 204	1,806,580	67 630	18,318	312	[illegible]	[illegible]
Factory Owners—Power only		99 973	-	99 973	1 120	1 095	11	[illegible]	[illegible]
Total	1,574,441	[illegible]	530 892	9,619,710	680 177	177 907	70,681	[illegible]	[illegible]
(B) FACTORIES RENTING PART OF THEIR POWER.									
	£000	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	1,000 [illegible]
Iron and Steel, Engineering & Shipbuilding Trades	28	40	—	40	—	—		40	
Metal Trades other than Iron and Steel	53	65	—	65		—		65	
Textile Trades	3,221	8,627	310	8,937	50	250		9,237	—
Total	3,302	8 732	310	9,042	50	250		[illegible]	[illegible]

* In addition to these particulars, the Board of Public Works, Ireland, returned the following:

	H.P.
Road Rollers, Locomotives, &c.	6
Other Engines	279
Electric Motors	10
	295

† In addition to these particulars, Local Authorities returned the following:

	H.P.
Road Rollers, Locomotives, &c.	[illegible]
Other Engines	[illegible]
Electric Motors	[illegible]
	166 897

‡ Excluding current purchased by certain Electricity Undertakings from other Electricity Undertakings.

AGRICULTURE. *In Great Britain in 1908 there were used on Farms for driving Machinery [illegible] Steam, Oil, Petrol, Gas and other Engines of [illegible] H.P.*

either steam plant or by gas engines. It is to be noted in this connection that the increasing adoption of modern forms of coke ovens is generally being accompanied by a more efficient utilisation of the coke oven gas in the production of power. The coke oven gas is of a high calorific value, and when properly purified, lends itself to use in gas engines.

(To be continued.)

THE PRESERVATION OF IRON AND STEEL STRUCTURES.*

BY F. CROSBY-JONES.

SOME of the agencies which hasten the corrosion of iron and steel are: (1) Alternate exposure to action of atmosphere and water; (2) the deposition of water in depressions, cracks, and crevices; (3) exposure to smoke, heated vapours, and acid gases; (4) damp and vitiated atmosphere; (5) the accumulation of soot, dust, decaying matter, &c.; (6) dripping water, fresh or salt; (7) stray electric currents, and electrolytic action; (8) several different classes of iron and steel incorporated in one structure; (9) inequalities of temperature. In some instances the agencies may be guarded against, but in many cases it is quite impossible to prevent them being present: therefore we must look to the improvement in the power of the metal to combat corrosion, or to a suitable protective covering.

Iron and steel, by their nature, are such that should we be able to incorporate with them some ingredient that would prevent corrosion, it would entirely alter their construction, and would probably render them useless for many of the purposes to which they are now put. If it did not do this, it would constitute such a material that existing methods of manufacture would be altered; in consequence, it is to manufacturers of iron and steel to whom we must look for any improvements in this direction. Until such are effected we must devise the best methods to protect the surfaces, and so preserve the body of the metal; or utilise existing methods, which include: (*a*) Covering by means of a non-corrodible, or less corrodible metal, and by a metal that corrodes and, being electro-positive to iron, thus will protect it during its life; (*b*) by coating with porcelain enamels, which are afterwards stoved; (*c*) by an oxidising process; (*d*) by Portland cement; (*e*) by paint, varnish, or bituminous solutions or compositions.

Electro-plating and Depositing.—Under this heading falls electro-plating and depositing in all its branches. This is a very efficient means of protection properly carried out, but is not applied to very large structures, owing to the size of tanks that would be required, and the amount of solution involved. The work is first pickled in hot dilute sulphuric or muriatic acid, after which it is thoroughly washed and brushed in water, then is immersed in an alkali bath to remove all traces of acid before proceeding to the depositing tank, where the desired metal is deposited on the material under treatment, by means of electricity. Galvanising is carried out by dipping into molten zinc by fire or acids. It is a good means of protection against ordinary atmospheric conditions, so long as the zinc remains, due to the fact that zinc is electro-positive to iron. Galvanised iron is readily affected by acids; in large manufacturing districts, roofs made of this material deteriorate quickly for this reason; whereas in country districts, where the atmosphere is free from acids, they endure for quite lengthy periods. The tinplate industry is another example of coating with metal. So long as the coating of tin remains intact all goes well, but as soon as the tin is abraded or wears corrosion makes rapid headway. Sherardising is a process by which iron is covered with a coating of zinc. The articles to be treated are thoroughly cleaned, and are then kept enclosed in zinc dust at a temperature of 300° C. for about one hour. This process gives a very uniform coating of zinc to the metal.

Porcelain Enamel.—This is applied in two or more coatings to the metal after it has been thoroughly cleaned by pickling. The first coating may be applied either in paste form or as a liquid; the second coat, in the case of paste, is a rather transparent enamel, and gives high finish; in the case of the liquid first coat, the second coat is of the same material. There are also several more or less secret processes as regards materials used, and method of application; but in all cases the articles treated have to be stoved. Its chief use is for advertisement plates, surgical, culinary, and household articles. Its disadvantages are that it does not stand vibration or ill usage, as it chips off readily, otherwise whilst its surface remains intact it is a perfect protection to the metal it covers.

Oxidising Processes.—There are several variations of these, the idea in all being to produce upon the surface of the metal magnetic oxide of iron. One way to accomplish this is to heat the object in a closed chamber, in the presence of a reducing gas, after which steam is blown over the heated metal.

Portland Cement.—This is porous to a certain extent; in thin layers, therefore, it affords little or no protection, but when used in such a way that iron or steel is embedded in a mass of it, it has proved to be a very efficient means of protection against corrosion. The alkali present in cement, while it is setting, prohibits corrosion, and in order to make cement a complete protection to iron and steel it is necessary that air and moisture shall not by any means have access to the metal, otherwise disastrous consequences may result, due to the expansion of rust formed between the metal and cement.

Painting.—This is the method of protection against corrosion that has the most extensive use, owing to the fact that paint is easy of application, and as a product is cheap; further, it has the advantage of being readily renewable to structures, where all other methods are impossible. Paints applied to iron and steel are engineering materials, and, as such, deserve more study and consideration by engineers; the "factor of safety" of iron and steel takes the effect of corrosion greatly into consideration; therefore if more care be expended upon the surface the factor might be lowered somewhat in certain cases, provided that sufficient care is given to surface preservation. Paint is not a destroyer of rust, nor will it last for ever, and will only protect iron or steel so long as it remains an adhesive and impervious coating. All paint undergoes alteration, as it absorbs oxygen from the atmosphere. The pigment used may accelerate this absorption. With a good paint on application, the oxygen absorbed is 10 per cent. to 15 per cent. of the weight of the oil used in the constitution of that film.

The properties of a good paint are, that it shall have no ill effects upon the metal itself, adhere firmly, be easy of application, be hard, tough, and elastic, adapting itself to changes of temperature, and form a smooth and even surface impervious to air, water, and gases. Paint should not remain soft underneath, and harden on the surface, and should not be softened by subsequent coats of paint, nor should it flake off, powder or blister; but gradually wear away as its life comes to an end. The duration of the life of paint varies considerably. On one occasion I had an engine room bulkhead chipped and scraped for the purpose of repainting. The ship was built of iron, and was 23 years old at the time. The coats of paint applied during service were readily removed, but the paint applied by her builders on the engine room side of the bulkhead could not be readily removed as it was so tough and adhesive, seeming to be ingrained to the metal. The iron on the engine room side was in a splendid state of preservation, except where it had been rusted through from the alleyways and tops of the bunkers: certain repairs were being executed at the time for this reason. The paint on the bunker side of the bulkhead was red lead ⅛in. thick. This could be chipped off in large flakes, leaving the metal quite bare.

The value of paint depends upon the nature, quality and preparation of the oils used; the character and proper selection of the pigment, and the care exercised in grinding and mixing; all of which means expert knowledge, constant attention, good machinery, and considerable expense; hence cheap paints are not to be relied upon. A great deal depends upon the manner in which painting is done, and the preparation of the work before commencement. It should be perfectly clean, free from grease, oil, or moisture, and all scale and rust should be removed. The most efficient method of cleaning iron or steel is by pickling, but unless all trace of acid be removed after pickling it might be a dangerous means of inciting corrosion; it is, however, not applicable to large structures. Sandblasting with dry, and not too sharp sand, is the most efficient means of cleaning metal in structural work that is already erected. Failing the last method, all

* Abstract of paper read before the Institute of Marine Engineers, January 19th, 1914.

scale should be removed with scaling hammers, that are not so sharp as to leave marks upon the solid metal, then steel scrapers and wire brushes used to remove all traces of rust, until the metal shows clean. All oil or grease should be removed by turpentine or benzine. Much painting is done upon metal when in a moist condition, and under such circumstances it is not to be wondered at that good results are not obtained. Wet and damp days should be avoided; the best results will be obtained when the metal is warmer than the surrounding atmosphere, thus avoiding the liability of condensation of moisture in the atmosphere upon the metal. Good stiff brushes should be used and the paint well brushed into the metal. A coat of paint should be well brushed out, and should be as thin as possible with due regard given to covering power. One coat of paint should be thoroughly set, not skinned over, before another coat is applied over it, otherwise the paint will soon begin to crack. The usual long handled brushes used in painting the hulls of ships are not at all good from a painting point of view, quite apart from the fact that they are the means of wasting much paint on the bottom of the dry dock; the reason being that the work is too far from the operator's eye for him to see if the surface is properly covered, and the paint well worked into the surface. All old paintwork that is to be repainted should be thoroughly washed down with clean fresh water, for the purpose of removing any matter that might be incorporated with the new coat of paint, and act in a harmful manner upon it; moreover, any loose paint should be removed. Within certain limits the longer a paint takes to set the greater its durability. A good paint, under normal conditions, will take eight to 12 hours to dry. Paints containing highly volatile ingredients should be scrupulously avoided as finishing coats, because the film will become porous on drying.

Too great importance cannot be attached to the fineness to which a pigment is ground; also to its thorough amalgamation with the medium with which it is mixed, in order to form a homogeneous mass, so that every particle may be impregnated with the medium; if this is not the case, the particles will absorb moisture and transfer it to the body on which the paint is applied. The medium in which a pigment is ground and mixed is of primary importance, as it is upon it the life of a paint mainly depends. The pigment is to give body to the paint, and it is advisable that it should be such, that of itself it should have no deleterious effect upon the metal, or to the medium with which it is mixed. Another important feature of a pigment is to protect the medium with which it is mixed from the action of the sun's rays where it is exposed to their influence, a paint in this respect is nearly always more durable than the medium of itself would be. Tar is not satisfactory either of itself or as a medium for the protection of iron or steel. It cracks badly under the action of the sun, and contains ingredients which hasten rusting. If these ingredients are removed, a material may be obtained which is fairly satisfactory for coating iron or steel not exposed to sunshine and air; such as for water pipes, &c., underground. Asphaltum is a natural bituminous material from which bituminous compositions and paints should be made, which will give good results used in enclosed spaces, where extremes of temperature do not exist, and the material is not exposed to sunshine and atmospheric influences.

Of paint mediums, linseed oil is the most widely known and extensively used. It belongs to the class known as drying oils, that are able to dry without the addition of driers, though this is seldom allowed to occur naturally, driers being added. There is a great deal of difference between the drying properties of various samples, and the endurance of a film of dried oil. This oil is now brought from many parts of the world and there is an ever increasing demand for its supply, which renders it more difficult to procure stored and matured oil. A good quality cold pressed oil may contain 5 per cent. of water, a hot pressed 10 per cent., and oil may be made to take up 20 per cent. of water by mechanical means. The complete elimination of all water and aluminous matter from oil is an essential feature in the preparation of paint suitable for ironwork. China wood oil has been used by the Chinese for centuries on their junks with splendid results in endurance; it is now used by many makers of ready-mixed paints, in conjunction with other oils, it causes paint to dry hard, and work well. It cannot be employed by painters who mix their own paints, as the treatment is not simply mixing, but a complicated process. Soya bean oil is derived from a particular class of bean extensively grown in Manchuria; it is sometimes used in the manufacture of flat paints, or may be compounded with other oils for certain other classes of paint. Menhaden oil is obtained from the menhaden fish, which is found on the North Pacific Coast of America; properly treated it is a useful oil in the preparation of heat-resisting paints.

Corn oil may be used in the preparation of paste paints in conjunction with linseed oil, it enables the paint to remain soft for a considerable period. A varnish made from china wood oil, or linseed, or both, in conjunction with hard gum resins, constitutes an ideal medium for ships' paints. The introduction of gum resins is by no means a new idea, having been used at as early a date as 1600 A.D. to form a protective coating to armour. The gum resins used are natural exudations from trees, and are endowed with various properties according to the source from which they are derived. They come from many countries, East Africa, Brazil, New Zealand, &c. Having been buried in the grounds for thousands of years, when dug up they are in a fossilised condition, and constitute some of the most permanent organic materials. The manufacture of varnish is an art which is the outcome of years of experience. Respecting pigments, there are but few that cannot be mentioned as being of themselves bad, in connection with some particular purpose; but combinations, in certain proportions, can, as a rule be made suitable to meet most cases. In order to illustrate the nature of some paints found to be best adapted for certain specified conditions, two different examples of ingredients contained are given as follows: (1) Zinc chromate, red lead, willow charcoal, asbestine, china clay, boiled linseed oil, raw linseed oil, china wood oil, varnish, turpentine, driers. (2) Zinc chromate, white lead, zinc oxide, willow charcoal, silica, boiled linseed oil, china wood oil, turpentine, driers.

Satisfactory paints can be compounded particularly applicable to each of the following conditions: (1) Funnel paints to withstand heat and retain colour in sea air. (2) Radiator paints in all colours to stand steam heat without blistering or chipping. (3) White enamels for all interior and exterior first-class work, either flat or glossy, and capable of withstanding sea air for lengthy periods. (4) Cork insulating paint upon which cork dust is applied, then varnished or painted. This prevents condensation by the retention of heat. (5) Refrigerator paints that will withstand hoar frost, &c. (6) Antifouling paints containing materials which arrest the growth of seaweed, molluscs, &c. (7) Fillers and rivet compositions for levelling up surfaces, which may be applied by knife or brush.

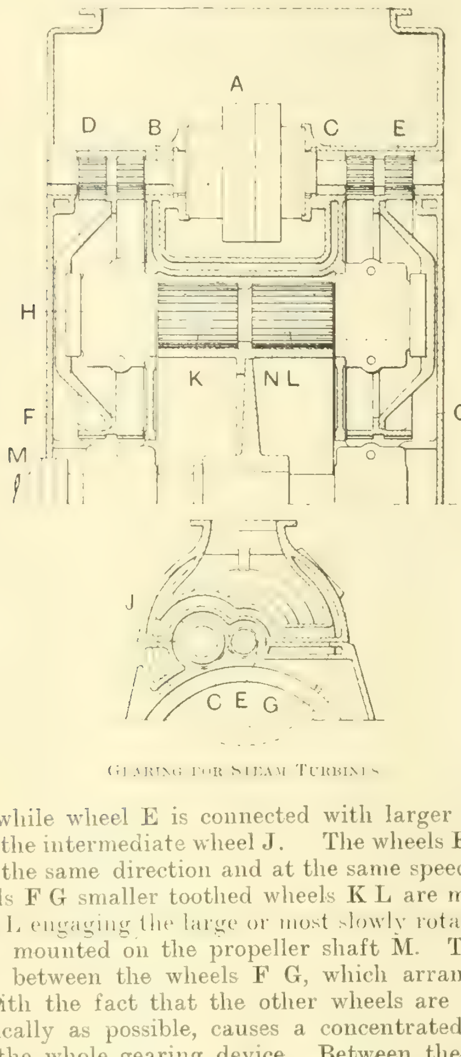
The constitution of all paints should be in accordance with the nature of the work that they have to perform, and should be compounded to give the best results obtainable under those conditions; therefore it behoves the engineer to give close study to these matters, and superintend the mixing of the best materials he can obtain for the purpose, or to put himself into the hands of a reputable firm of manufacturers, advising that firm of the exact purpose for which the material is to be used, when he should obtain an even better result if only due to the more intimate mixing and grinding of the material.

In conclusion, all structures should be composed of the same metal as far as other considerations will allow; surfaces should be even and free from depressions, cracks, and crevices wherein water can lodge; pockets that allow of the collection of water should be avoided; all members should have free air circulation about them; provision should be made, where necessary, for the drainage of water; joints, rivet heads, bolts, and nuts should be given special attention to ensure exclusion of water, and all parts that are not easily visible should have careful inspection. When painting has to be done it is advisable that each coat should be of a different shade in order to facilitate inspection and to check the number of coats used. Above all, before a protective coating is applied the metal must be clean and dry, then a good material used, and the work must be properly carried out.

Cobalt Tool Steel.—The Patent Office at Berlin has, states "The Ironmonger," granted the full patent, without restrictions, for the manufacture of Cobalt tool steel, to the Becker Steelwerke, of Willish, Germany. The application was opposed by the leading tool steelmakers of the Continent, but their objections were overruled by the authorities.

GEARING FOR STEAM TURBINES.

AN arrangement of toothed gearing for steam turbines of the double rotation type, having two shafts disposed in the same axial line, and which have a high speed of rotation and are adapted to drive propellers, is shown in the accompanying sectional views. A indicates the turbine, which is of the double rotating type, so that the two shafts B and C rotate in opposite directions. On these shafts toothed wheels D E are mounted, which gear with the larger toothed wheels F G mounted on a common shaft H, the wheel D gearing directly



GEARING FOR STEAM TURBINES.

with F, while wheel E is connected with larger wheel G by means of the intermediate wheel J. The wheels F G will thus rotate in the same direction and at the same speed. Between the wheels F G smaller toothed wheels K L are mounted, the wheels K L engaging the large or most slowly rotating toothed wheel N, mounted on the propeller shaft M. The wheel N is placed between the wheels F G, which arrangement, together with the fact that the other wheels are arranged as symmetrically as possible, causes a concentrated and stable form of the whole gearing device. Between the shafts B C on the one hand, and the shaft M on the other hand, the number of toothed wheels will be odd on the one side and even on the other side. The arrangement is the invention of Aktiebolaget Ljungströms Angturbin, of Liljeholmen.

OIL AS FUEL.

AT a meeting of the Institution of Engineers and Shipbuilders in Scotland held in Glasgow on the 20th inst., a paper was read on "Oil Fuels and their Application to the Generation of Power," by Prof. Thomas Gray, D.Sc., Ph.D., and Prof. A. L. Mellanby, D.Sc. The rapid extension of the use of oil fuel during recent years was, they pointed out, due initially to the accumulation of large stocks of petroleum, available at low prices, but the present widespread demand was attributable largely to a more general recognition of the greater convenience and efficiency of oil as compared with coal, and also to the development of the Diesel engine. The bulk of the petroleum employed at present for the generation of power was burned under steam boilers. Distilled oils from petroleum and tar and some crude oils had been extensively used in Diesel motors, but much work remained to be done before it could be asserted definitely that that type of engine was capable of dealing successfully with the many varieties of petroleum which occurred naturally.

The evaporative efficiency of oil, if atomised thoroughly in a well-designed burner, was approximately 50 per cent. greater than that resulting from an equal weight of good steam coal. That did not, however, represent the relative values of oil and coal as fuels in actual practice. The decreased labour charges and other advantages of firing with oil must also be taken into account. Regarded solely from the standpoint of fuel efficiency the oil engine was admittedly far superior to the combination of boiler and steam engine, but the question of the relative costs of generating power by the two systems depended also on other factors, and could only be answered when the conditions under which the plant operated were specified. The initial cost of a Diesel installation was considerably greater than that of a steam engine and boiler, and the higher interest and depreciation charges might more than counterbalance the saving in fuel costs. In localities where the cost of fuel was high, and the engine was running continuously, the fuel charge represented a large item in the total cost, and the advantage lay with the Diesel installation. If, on the other hand, fuel was cheap and the load factor low, the fuel costs were relatively small, and the conditions were unfavourable to the operation of the oil engine. The relative prices of oil and coal were obviously an important factor in the comparison of costs.

The total world's production of liquid fuels of all kinds amounted to less than 55,000,000 tons, and represented only about 5 per cent. of the world's coal production, and the widely-quoted prediction that oil was the fuel of the future had therefore very little prospect of fulfilment. It was true that the oil-bearing regions of the world had as yet been imperfectly explored, but the older fields in the Eastern States of America, and in Baku, which supplied the bulk of the world's production of oil for generations, showed unmistakable signs of exhaustion. So far as present information went there was no justification for the belief that the predominant position occupied by coal as a source of power and heat would ever be seriously threatened by oil fuel.

The position in Great Britain, remote from the principal oilfields of the world, with plentiful supplies of coal in the neighbourhood of the large industrial centres, was particularly unfavourable to the extension of the use of oil fuel. We depended for our liquid fuel largely on the surplus production of other countries, and recent developments pointed to the disappearance of this surplus in the principal oil-producing countries in the near future. For an assured supply of liquid fuel in this country we must depend on the development of the shale oil industry, and the distillation of coal at low temperatures.

Birmingham Foundrymen's Association.—At a recent meeting of this association Mr. S. G. Smith read a paper on "Loam Moulding." By this process, he said, castings could be made up to 10ft. diam. in one piece, and varied in length and thickness, being often strengthened internally with additional flanges. The loam moulder's daily routine was with spindles, plates, bricks, straight edges, square stricking boards, strickles, &c. The sand moulder's concern was with various kinds of patterns, boxes, &c. In loam casting the preparation of the tackle to be used was most important. Mr. Smith pointed out the care necessary to provide for adequate bricking, and cautioned his audience against a too "sloppy" or too stiff consistency of loam, or of "blacking" the moulds when hot.

Institution of Naval Architects.—The annual meetings of this institution will take place on Wednesday, April 1st, and the two following days, in the hall of the Royal Society of Arts, John Street, Adelphi, W.C. (by kind permission of the Council). The Most Hon. the Marquis of Bristol, R.N., president, will occupy the chair. The annual dinner will be given on Wednesday, April 1st, at 7-30 p.m., in the Grand Hall, Connaught Rooms, Great Queen Street, Kingsway, W.C. The Council will be willing to present a gold medal to any person not being a member or associate member of Council who shall at the forthcoming meetings read a paper which, in the judgment of the Council, shall be deemed to be of exceptional merit. The Council will also be willing to present a premium of books or instruments to the reader of any paper, not being a member or associate member of Council, which paper shall in the judgment of the Council merit this distinction.

THE MEASUREMENT OF STRESSES IN MATERIALS AND STRUCTURES.*

BY PROF. E. G. COKER, M.A., D.SC.

(Continued from page 86.)

A CONSIDERABLE amount of investigation has been carried out by Messrs. Wilson and Gore with models made of india-rubber, and a simple example of stress determinations of this kind relates to the effects of groups of rivets in plates subjected to tension. In these experiments a plate of rubber is laid upon a table with a plate-glass top, there being a number of steel balls between the model and the glass to avoid frictional resistance. The model is marked off with circles of suitable diameters, and these latter are photographed before and after loading, and the negatives so obtained are then placed on the table, and the directions and magnitudes of the strains are measured with a very accurate micrometer.

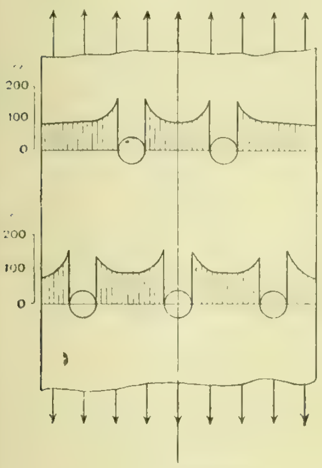


FIG. 12.

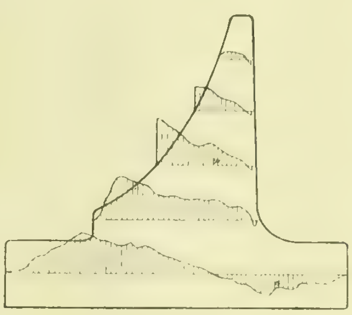


FIG. 13.

Having obtained the strains from measurements of corresponding parts of the two photographic plates, the principal stresses p and q are computed by equations I. and II., which, together with the measured directions, give an experimental solution. An example of the stress distribution obtained is shown in Fig. 12, in which a tension member has two transverse lines of holes filled with india-rubber plugs to represent rivets. A considerable alteration occurs in the distribution of stress in the plate owing to these discontinuities, and is especially marked along the lines of the cross-sections passing through the rivets. Great increases in the tension stress p occur close to the edges of the holes, and a transverse compression stress q is also caused by the resistance of the rivet to compression; stress distribution around each rivet is, in fact, very complicated. Some of the most important modern researches on stress distribution in structures have been accomplished by measuring the strains in models composed of materials which give large deformations with moderate loads, and in this country great attention has been paid to the stress distribution in masonry dams as a result of the theoretical and experimental researches of Prof. Karl Pearson and his associates.

The fundamental conception of the ordinary theory of stress distribution in a masonry dam is based on the assumption that the distribution of normal stress across horizontal sections is linear; and if this be so, it is not difficult to show that the shear stress along the same section must be distributed according to a parabolic law. Such a theory neglects many of the most important stresses which have an important bearing on the stability of a dam; and measurements by Atcherley and Pearson of the strains in models demonstrated the existence of stresses of which no account had been previously taken, such as the considerable tensional stresses which exist at the angle between the vertical and horizontal water faces, and also at the tail of the dam and in the substratum under the tail. It is a matter of importance to note that in this type of structure the weight of the dam itself produces stresses of the same order of magnitude as the water pressure on the face, and hence the material of a model must be such that both the weight and the applied load can be adjusted to the proportions in which they occur in practice, and yet be of such magnitude that the strains from each are measurable. After repeated trials a heavy elastic material was obtained, made of gelatine, glycerine, and colouring matter, which fulfilled these requirements, and models of the cross-sections of such well known structures as the Assouan Dam and that at Vyrnwy were constructed, and the distribution of strain investigated, especially the shear strains, which were measured by aid of a goniometer constructed to measure the small changes of angles of squares ruled on the cross section. Some of the measurements are given in Fig. 13, which shows a section of a model of the Assouan Dam with the curves of shear strain plotted at a few of the horizontal sections; and it is evident that the distribution of shear stress is not even approximately parabolic, as the ordinary theory indicates.

The stress distribution in model dams made of india-rubber has also been the subject of experiments by Messrs. Wilson and Gore; and as india-rubber is not sufficiently heavy to give measurable strains due to its own weight, it was found necessary to apply loads to every part of the model, and so obtain virtually an artificial increase in the density to give the correct relation between the applied loads representing water pressures and the weight of the model itself. Each element of the section was therefore perforated to receive a spindle, from which weights of the necessary amount were suspended, and the action of the water pressure was imitated by loads directly applied to the water faces. The directions and magnitudes of the principal strains were determined from the changes produced in circles marked on the cross section, which latter was photographed before and after loading, and the stress distribution inferred from measurements of the changes in the shapes of these circles of reference.

The methods adopted in this group of researches on a single problem of great practical importance are thus seen to be widely different, both as regards the way in which loads are applied and strains are measured; but, in spite of this, there is a very substantial agreement in the main conclusions as to the stresses which are experienced in these structures, and the investigations are notable examples of the great value of strain measurements where methods of calculation are known to be inadequate and fail to give accurate information. The literature of this branch of science provides numerous other examples of technical interest which might be suitably referred to here, but those cited are probably sufficient to show the great scope of this kind of experimental work for determining the stress distribution in proposed structures or in those already constructed.

The methods of strain measurement have now been examined at some length, and we have seen how difficult it is to approximate to the ideal of measurement the stress at a point. The change of a form of a body under stress is one only of the properties useful for the determination of stress distribution, another is the thermal change accompanying applications of load to which attention was first drawn by Weber. It is well known that some materials when tested to destruction show a considerable rise of temperature at the section of fracture, but Weber found that, within the elastic limit, a slight cooling takes place when a pull is exerted. His experiments and calculations demonstrated that the change in temperature is proportional to the applied stress, and also to the coefficient of expansion of the material. Beyond the elastic limit of a metal a rise of temperature of relatively large magnitude

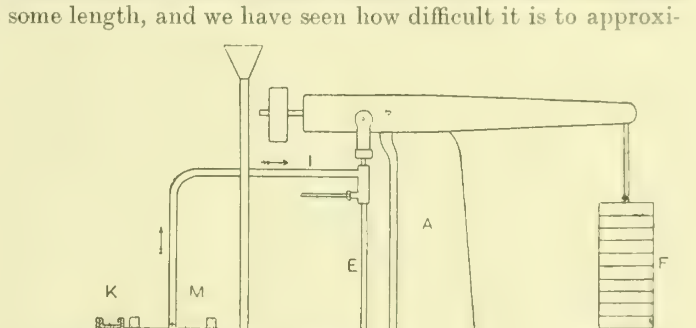


FIG. 14.

* Cantor lectures delivered before the Royal Society of Arts, December, 1913, and reproduced from the Journal of the Society.

occurs in ductile metals with all kinds of stresses. The thermal changes produced within the elastic limit were more fully investigated later by Sir William Thomson, who deduced the general equations of thermo elasticity from the principles of thermo dynamics, and showed that the thermal effect for small stresses is strictly proportional to the stress intensity. The various factors which influence the change may be illustrated by the simple case of a tensional stress in which the change of temperature $\triangle t$ for a small change of stress $\triangle p$ is expressed by the formula:—

$$\triangle t = -\frac{t\,a}{J\,s\,\rho}.\triangle p. \qquad \text{(III.)}$$

where a is the coefficient of expansion of the material.

s the specific heat at constant pressure,

ρ the density of the material, and the minus sign indicates a diminution of temperature.

In order to show the magnitude of the effect produced by different intensities of stress, we may take the case of a steel bar of density 7·5, and having a specific heat of 0·11 at 20° C., a being $1{\cdot}2 \times 10^{-5}$. This gives:—

$$\triangle t = -{\cdot}000012\ \triangle p$$

approximately, from which the changes in temperature produced by different amounts of stress can be readily calculated, as Table IV. shows, and we find that it required a stress of

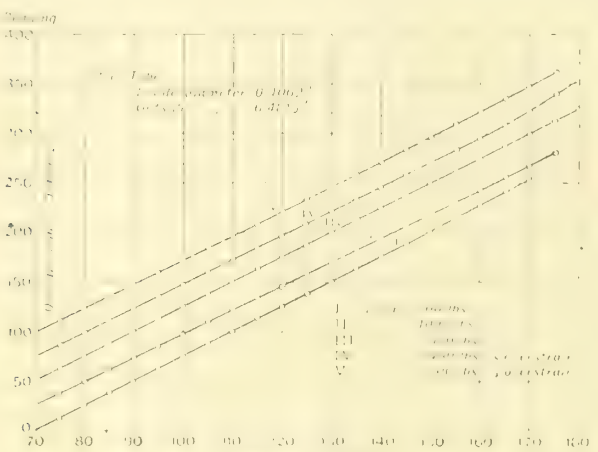


FIG. 15.

20,000 lbs. per square inch to produce an alteration of one quarter of a degree on the Centigrade scale, a decrease for tension and an increase for compression, provided the law

TABLE IV.

Tension or Compression Stress in lbs. per sq. in.	Temperature (Centigrade).	
	Tension.	Compression.
0	20·0	20·0
5,000	19·94	20·06
10,000	19·88	20·12
15,000	19·82	20·18
20,000	19·76	20·24

holds for such great intensities. Elastic failure is accompanied by a considerable rise in temperature altogether masking the effects described above.

In considering the application of thermal effect to the practical testing of materials, it is important to note that the change of temperature is inversely proportional to the specific heat of the material, and this may vary under stress. There appears to be no direct experimental evidence on this point, but it seems very unlikely that any appreciable change can take place. Theory also shows that the coefficient of expansion is a factor in determining the change of temperature, and equation III. shows that if a material behaves abnormally, and contracts with a rise of temperature, the thermal effects are then reversed. India-rubber, as is well known, possesses this curious property, and the heating effect produced when it is suddenly stretched is distinctly perceptible.

As the coefficient of expansion is a factor of equation III., it is important to know if any variation is produced by stress. This has been examined experimentally for metal tubes subjected to stresses over a range extending beyond the elastic limit of the material, the required temperature being obtained by hot water circulating through them. The general arrangement of the apparatus for examining the effects of stress upon the expansion is shown by Fig. 14, in which a testing machine A, of the single-lever type, is used to stress a metal tube, E,

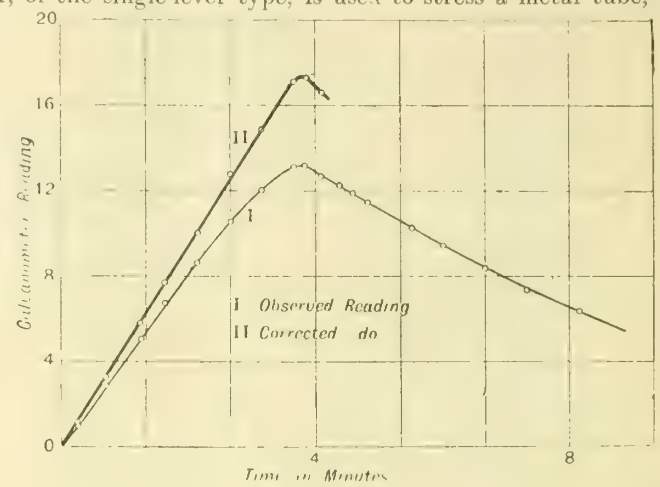


FIG. 16.

secured in suitable holders, while its temperature is maintained at any desired point by circulating hot liquid through the interior of the tube. The liquid is heated in a vessel, M, provided with a motor-driven centrifugal pump, K, for circulating the liquid through the tube under test. The expansion is determined by a delicate extensometer, and some of the measurements for a steel tube are shown in Fig. 15. It will be observed that the load has very little effect, and indeed the following extensions (Table V.), obtained on a length of

TABLE V.

Mild Steel Tube. Temperature range 70° Fah.–170° Fah.	Within the Elastic Limit.			Permanent Stretch.	
				⅛ in.	¼ in.
Stress in lbs. per sq. in.	1,490	14,930	29,850	35,820	37,160
Extensions in hundred-thousandths of an inch	508	486	500	500	484

ten inches, show that even stresses causing considerable permanent stretches in the material produce little effect upon the thermal expansion of the metal. A brass tube tested in the same manner gave greater variations beyond the yield point,

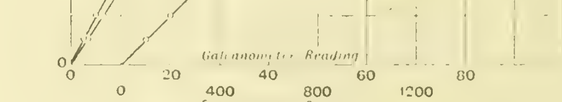


FIG. 17.

as appears from Table VI., but the measurements within the elastic limit of the material show that no appreciable change takes place.

TABLE VI.

Brass Tube. Temperature range 70° Fah. 170° Fah.	Within the Elastic Limit.			Overstrain.		
Stress in lbs. per sq. in. ..	9,600	19,200	33,600	$\frac{1}{16}$ in.	⅛ in.	¼ in.
Extensions in hundred thousandths of an inch	852	856	858	878	882	942

As we have seen, the change of temperature which a bar experiences when loaded is very small, but fortunately thermo-electric methods of measurement are so delicate that differences of temperature of one thousandth of a degree Centigrade, or even much less, are not difficult to measure with suitable appliances, and by the use of thermo-electric couples inserted in the material, Joule was able to verify the truth of the Thomson law for a considerable number of materials subjected to tension and compression stresses. For ordinary laboratory experiments it is often convenient to use

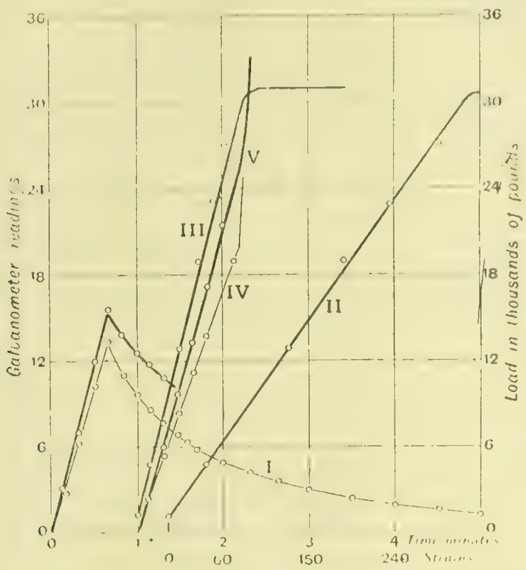


FIG. 18.

a bismuth-antimony thermopile pressed against the surface of the test bar, and in circuit with a delicate galvanometer. As an example of a test carried out in this manner we may take the case of a steel tension member subjected to a gradually increasing load, in which the rate of loading with time is preferably arranged to be as uniform as possible, since, as will appear, a correction must be applied to the readings of the galvanometer, which depends upon this time factor. An experiment arranged in this manner gave the following galvanometer deflections (Table VII.) to an arbitrary scale, and these are plotted on a time base in Fig. 16, from which latter it seems as if there is no linear relation between the stress and the thermal change. The experiment also shows that while the load is maintained at a constant amount of 16,000lbs., the galvanometer readings grow less and less as the time increases, because the bar tends to resume its state of thermal equilibrium with surrounding bodies. The readings there required correction by some function, which, it is easy to see, must depend on the time during which the equilibrating forces act, and also on their effectiveness.

TABLE VII.—*Steel Tension Specimen* 2·00 *by* 0·375*ins. in Cross Section.*

Total Load. Lbs.	Time. Seconds.	Galvanometer Reading.	Corrected Reading.
500	0	0	0
4,000	15	2·8	2·97
8,000	100	6·8	7·71
12,000	160	10·3	12·80
16,000	220	13·1	17·08
16,000	247	12·9	16·62
16,000	362	9·2	13·80
16,000	555	5·4	9·54

If we assume that, for these small differences of temperature, the thermal effect of surrounding objects upon the bar is proportional to the first power of the temperature difference, it can be easily shown* that the observed reading D_t at any time t must be corrected by adding thereto a quantity $\frac{1}{2}ctD_t$, where c is a coefficient obtained from the curve of observations in Fig. 16 and t is the time from the commencement of the loading. In the present example c = ·0026, and the readings corrected for the radiation and conduction effects are given in Table VII. and are also plotted in Fig. 16. The results now show that the change of temperature bears an approximately linear relation to the load applied to the specimen. If a bar is subjected to a tensional test which gradually increases up to the yield point of the material, both the strain and the thermal effect give a linear relation to the stress up to the elastic limit, but beyond this they both diverge from a linear law, although in different ways—the strains increase very much, but the thermal effect is rapidly reversed and a comparatively great rise of temperature is indicated. This latter phenomenon may, in fact, be utilised to determine the elastic failure.

The general type of results obtained may be illustrated by a tension test on a steel bar in which extensometer readings are taken, in addition to the thermopile indication. The observed and corrected galvanometer readings are shown in Fig. 17 to the same scale of loads and to different horizontal

TABLE VIII.

Time. Seconds.	Load. Lbs.	Extensometer Readings.	Galvanometer Reading Time. Seconds.	Observed Readings.	Corrected Readings. k = ·00985
0	1,000	0	0	0	0
12	5,000	46	10	2·0	2·01
– –	9,000		20	5·5	6·05
32	13,000	129	30	8·5	9·8
·	19,000	186	40	11·2	13·1
55	23,000	236	50	13·8	17·2
65	27,000	286	60	16·4	21·5
70	29,000	·	70	19·1	25·8
79	30,000	yield point.	80	44·0	61·5
			went off scale.		

scales of galvanometer and extensometer readings, which, however, have a linear relation to one another and to the time of observation. They show almost complete linear correspondence right up to the elastic limit of the material, and, in fact, afford a practical means of detecting this limit quite independently of mechanical measurements. The thermal effects produced by compressing a metal differ from those produced by tension in that there is a continuous rise

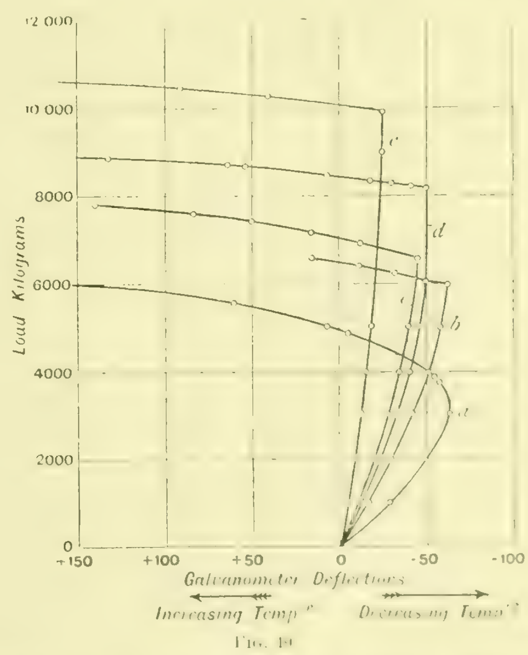


FIG. 19

of temperature. There is a small increase proportional to the load within the elastic range, and a sudden and great increase when this limit is passed, which is apparently dependent upon the character of the material and its crystalline structure.

The changes which occur may be conveniently illustrated by some results obtained from a short specimen which was subjected to a pure compression stress in a hydraulic press.

* On the "Measurement of Stress by Thermal Methods," by E. G. Coker. "Transactions," R.S.E. Vol. XLI. 1901.

The correcting factor was first obtained by a preliminary experiment within the elastic range of the material (I., Fig. 18), and the second part of the deflection time curve shows that it has a value of ·00985. A strain-measuring instrument was afterwards secured to the specimen, and adjusted until a unit reading upon the scale corresponded to $\frac{1}{250000}$in., the measured length being $1\frac{1}{4}$in., and a further test was made in which the load on the specimen was increased until failure took place. For convenience of working, there was an initial load of 500lbs. upon the specimen. The observations in Table IX. and Fig. 18 show that the yield point noted by the strain-measuring instrument was observed at almost precisely the same instant that the galvanometer recorded a sudden and great increase of temperature. This is more clearly seen when the observations of strain and thermal change are plotted upon a common time base, as in curves III., IV., and V., all of which mark the yield point by abrupt changes. It is also worthy of note that the corrected readings of the galvanometer are proportional to the load until very close to the yield point, so that, having established this relation, we may utilise the sudden increase of temperature to show when breakdown occurs. This sudden change in the thermal condition of a metal has, in fact, been utilised for determining the yield point of a material, as, for example, by E. Rasch* and Messrs. Lawson and Capp.*

An example of such tests is furnished by the results of the former experimenter on an annealed brass rod which was subjected to a gradually increasing pull until the yield point of the material was passed. The changes in the galvanometer, reading with the load, are shown on the accompanying Fig. 19 (curve *a*). On repeating the test upon the same material after an interval, a reversal of direction of the galvanometer reading occurred later (curve *b*) showing a higher yield point, while further tests in the same manner show still further rises of the yield point, as the curves *c*, *d*, and *e* indicate. In cast iron the change of direction did not, however, occur until the instant of fracture.

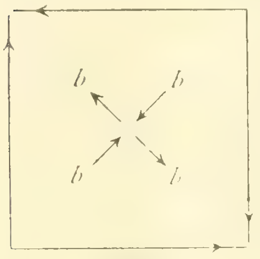


FIG. 20.

It is an advantage of thermal measurements that apparently the effect of shear stress within the elastic limit is not accompanied by thermal change, and a special experiment to detect if any thermal change occurred in the case of cylindrical bars subjected to a pure twist failed to show any thermal change within the elastic limit of the material. This result can be readily explained by considering the effect of equilibrated shear stresses of intensity distributed over the faces of a cube (Fig. 20). At any point of the interior of the cube their effect may be represented by a tension stress q, accompanied by a compression stress q at right angles and both equally inclined to the sides of the cube. The two stresses therefore produce thermal changes of equal amounts and opposite sign, and the total effect is zero. The result that equal and unlike principal stresses produce no thermal change is noted here, because it may possibly be of service, in combination with optical methods, described later, for mapping stress distribution in complicated cases. It will also be apparent that a thermo-couple can be used to determine the algebraic sum of the principal stresses at any point of a body, whether at the surface or within it, although these latter determinations involve cutting away a part of the material, and thereby possibly introduce a grave source of error owing to the discontinuity.

(To be continued.)

* Proceedings of the International Association for Testing Materials, 1909 and 1912.

Iron Pots for Melting Cyanide.—Large quantities of cyanide are now used for case-hardening steel, and it is used in the molten condition. Iron pots have, says "The Brass World," always been used for this purpose, with satisfactory results, and are, of course, cheap. Nickel stands molten alkalies better than other common metals, and potash or soda can be melted in them without danger of the vessel being attacked. It is possible that cyanide can be melted in a nickel kettle satisfactorily and obtain a much longer life on it. As far as known, this has not been tried.

INDUSTRIAL AND TRADE NOTES.

Britain's Imports of Oil.—According to the "Petroleum Review," over 420,000,000 galls. of oil were imported into the United Kingdom during 1913. Of this total, 102,644,080 galls. represented motor spirit, 156,894,623 galls. illuminating oil, and 65,705,048 galls. lubricating oil.

New Tube Works for Newport.—The British Mannesmann Tube Company has, says the "South Wales Daily News," definitely decided to establish tube works at Newport, where a site costing about £46,000 has been acquired. It is expected that when the works are complete about 3,000 men will be employed.

A Large Wind Motor.—What is claimed to be the largest wind motor in the world has lately been brought into use at Harlingen (Friesland) for drainage purposes. This machine, which has steel sails and is mounted on a steel tower, has a diameter of 15 m., and is capable of dealing with 1,800 c.m. to 2,000 c.m. of water an hour. The machine was supplied by Messrs. R. S. Stockvis and Zoon, of Rotterdam.

Rating of Engines and Boilers in Empty Premises.—A case of interest to mill owners and steam users was heard before the Todmorden magistrates on the 22nd inst., when the Calderside Dyeing Company, Hebden Bridge, were summoned by the overseers of Hebden Bridge for the non-payment of rates in respect of their mill, which is empty except for an engine and boiler. The defendants contended that the mill, being empty, there was no beneficial occupation, and they were entitled to exemption. On the other hand, the overseers maintained that the premises were being used to warehouse the engine and boiler, and that the defendants were deriving beneficial occupation and ought to pay rates. After hearing the arguments the Bench stopped the case, and decided against the overseers, but consented to state a case for appeal.

A Large Rolling Mill Engine.—Messrs. Richardsons, Westgarth, and Co., engineers, have constructed at their Middlesbrough works a rolling mill engine of 25,000 h.p. It is of the three-crank vertical type built to the order of the South Durham Steel and Iron Company to their designs and under the superintendence of their chief engineer, Mr. Edward Crowe. It will be used for driving a plate mill at the company's malleable works, Stockton-on-Tees. The engine is arranged for direct driving, so that all gearing between the engines and the mill is entirely dispensed with. The three cylinders are 54in. diam. by 60in. stroke, the engines being designed for a speed of 80 revs. per minute in ordinary work and a runaway speed of 240 revs. per minute. The working pressure is 160lbs. per square inch, and the engines are capable of developing a total of 25,000 h.p. The valve gear is of the Joy type specially designed for rolling-mill work, and the whole of the engine control is by means of a single lever actuating the Crowe Davy starting and reversing gear.

Regulation of Prices in the Galvanised Iron Trade.—The monthly report of the Steel Smelters' Association states that the arrangement for regulating prices in the galvanised sheet trade has resulted in a good deal of speculation as to the probable effect upon the trade. It is reported that all the makers in the country are parties to the scheme, which differs in several respects from that which was in operation prior to 1910. The object is to check competition, and to keep prices within such a limit as to prevent a repetition of the experience which brought about the termination of the old agreement. It is intended to maintain strict control of output, and to each firm will be allotted an output based upon their production for the past three years. Firms exceeding the limit will pay a proportionate contribution to the pool, while firms whose output falls below the limit will be recouped from the pool. When prices fall below a level at which they cease to be remunerative the output of the various works will be curtailed until the demand enables profitable prices to be obtained. The working of the scheme will be watched with interest.

Green's Economisers.—Messrs. Green & Son, Ltd., of Wakefield, the well-known makers of economisers or feed-water heaters, have sent us a copy of an interesting and instructive book they have just issued for the use of engineers and steam users concerned with the design or working of their apparatus. The book gives an historical review of the development of their apparatus from the time of its first introduction by the late Mr. Edward Green in 1845 down to the present day, as well as the various reasons that have gradually led up to the adoption of their latest designs, suitable for boilers of almost every type and pressure. The book is beautifully illustrated with photos of economiser details and accessories, as well as of installations at work in various parts of the world, and a series of working plans for the guidance of engineers and others in arranging boiler houses and flues to suit varying types of boilers, dispositions of building sites, chimneys, &c. The whole is supplemented with a mass of useful

data, records of working tests, &c., which should be of great service to all interested in the working of this apparatus, and constitutes a work of reference which well deserves a prominent place on the office bookshelf.

Water Purification. Messrs. Mather & Platt, Ltd., of Manchester, have recently completed three extensive schemes of water supply and filtration, and they have in hand several other contracts of a similar nature. Towards the end of 1912 they completed a scheme of water supply and filtration at Loxley Valley for the Sheffield Corporation. This installation has been working regularly during the past year, and supplies the town with about 7,000,000 gallons of pure water per day. The Sheffield Corporation have since placed an order with the firm for a further installation of filters. Installations have been recently completed by Messrs. Mather & Platt for the Rhymney and Aber Valleys Gas and Water Company, the Fraserburgh Corporation, and the Brindley Bank Pumping Station of the South Staffordshire Water Company. Other recent contracts include filters for the Newquay and District Water Board, the Salford Corporation Electricity Works, the Oldham Corporation, the Accrington Electricity Works, and the Paisley Corporation. In addition, they have in hand several contracts for abroad. Messrs. Mather & Platt are in a position of advantage in the carrying out of schemes of water filtration and purification, inasmuch as, although there are many firms who manufacture filters, water softeners, and sewage plant singly, they are the only firm who manufacture appliances for the whole three sections. They are consequently familiar with all the details necessary for the effective carrying out of either municipal water purification work or the installation of an industrial filtration scheme.

Alcohol as Motor Fuel.—The following have been appointed on the Alcohol Motor Fuel Committee formed by the Imperial Motor Transport Council: The Hon. Arthur Stanley, M.P., M.V.O., chairman of the Royal Automobile Club, &c. (chairman); Mr. Thomas L. Aveling, nominated by the Royal Agricultural Society; Mr. Bertram Blount, consulting chemist to the Crown Agents for the Colonies; Mr. J. Sidney Critchley, the president of the Institution of Automobile Engineers; Mr. S. F. Edge, president of the Society of Motor Manufacturers and Traders; Mr. S. Glover, gas engineer to the Corporation of St. Helens; Dr. H. S. Hele-Shaw, formerly chairman of the Motor Union Fuel Committee, representing the Automobile Association and Motor Union; Mr. Basil H. Joy, secretary of the Institution of Automobile Engineers, representing with Mr. Critchley the Institution of Automobile Engineers; Prof. Vivian B. Lewes, Professor of Chemistry at the Royal Naval College, Greenwich; Dr. W. R. Ormandy, Bishop Berkely Fellow of Owens College, Manchester, who has carried out important investigations on the use of alcohol and alcohol mixtures as a fuel for motor engines; Sir Boverton Redwood, Bart., Advisor on Petroleum to the Government; Mr. Sidney Straker, chairman of the Commercial Vehicles Committee of the S.M.M. and T.; Mr. Thomas Tyrer, member of the Council of the London Chamber of Commerce; Mr. Horace Wyatt, honorary secretary of the Imperial Motor Transport Council. It is the intention of the committee to conduct investigations into the possibility of obtaining adequate supplies of alcohol suitable for motor fuel at sufficiently low prices. Also, to direct experiments tending towards the production of engines suited to employ alcohol as a fuel.

Long-distance Cabling.—At a meeting of the Dominions Royal Commission held in London a few days ago some interesting information relating to long-distance cabling was given by Mr. F. C. Crawford, chief of the submarine cable laying department, and Mr. Rollo Appleyard, chief of the submarine core manufacturing department at the Silvertown Works. They explained that the general effect of recent developments was that speed had been increased by 50 per cent. or more, and that accuracy of transmission had been improved. The cost of a modern Atlantic cable, giving a speed of about 40 words per minute, was about £500,000, depending on fluctuating markets and the cost of the materials. Mr. Crawford said that as regarded short cables and land lines working with the Creed, Baudot, and other systems the speed was far ahead of long-distance cable working, but he had no doubt that distinct improvements would be made in the future for long-distance working. Mr. Appleyard said he saw no prospect of there being any reduction in the cost of construction and working of cables. The tendency of the market in raw materials, whether in jute, copper, or gutta percha, was to rise. In the event of the Government desiring to own a cable service across the Atlantic it would be desirable, in order to secure an efficient and reliable service, to have two cables. Referring to the relative merits of cable and wireless systems, the witness said the ordinary cable was more constant, more trustworthy, and certainly more secret. The advent of wireless had in no way diminished the activities of the cable companies; in fact, the tendency had been in the opposite direction. It had stimulated and encouraged them to further development. He could not see how wireless could ever possibly supersede the other system. It might be possible to increase the speed of wireless, but he did not see how it could ever become a secret system.

World's Coal and Iron Production.—Part IV. of the Annual Report of the Chief Inspector of Mines and Quarries for 1911, just issued from the Home Office, gives particulars relating to persons employed, output, and accidents at mines and quarries in the British Colonies and foreign countries. From this it appears that the number of persons engaged in mining and quarrying at home and abroad in 1911 reached nearly 6,500,000. Of this total, roughly speaking, nearly one fifth were employed in the United Kingdom, and more than one-third in the British Empire. No statistics, however, are published by several countries in which mining is carried on, and the figure probably falls considerably short of the real total. More than half of the total number were employed in getting coal alone, Great Britain employing nearly 1,050,000, the United States over 722,000, Germany nearly 701,000, France over 200,000, Russia (1909) over 169,000, Belgium over 144,000, Austria over 129,000, and India over 116,000. The total amount of coal produced was nearly 1,187,000,000 metric tons, the value of which is estimated at nearly £435,000,000. The quantity and value compared with 1910 show an increase of nearly 23,000,000 tons in the output, and of over £15,000,000 in the value. The leading countries are: United States, with a production in round figures of 450 million metric tons, valued at 128 millions sterling; Great Britain, 276 million metric tons, valued at 111 millions sterling; and Germany, 234 million metric tons, valued at 88 millions sterling. In the case of iron, the United States, with an output of nearly 23,700,000 tons, is considerably ahead of any other country. The German Empire with over 8,500,000 tons, Great Britain with over 5,100,000 tons, France with nearly 5,900,000 tons, and Spain with over 1,400,000 tons, come next. As regards the loss of life from accidents in mines and quarries, and the death rates from accidents per 1,000 persons employed, and taking coal mines, for which the figures are fairly complete, it is seen that the death rate of the United Kingdom was 1·17, and for the British Empire 1·25, while for Austria it was 1·27, Belgium 1·14, France 1·08, Japan 3·42, Germany 2·08, and the United States 3·55. The death rate for foreign countries generally was 2·51.

THE MANCHESTER STEAM USERS' ASSOCIATION.

THE annual memorandum of Mr. C. E. Stromeyer, the Chief Engineer of the Manchester Steam Users' Association, for 1912 has just been issued. The memorandum, which is of a very technical character, is devoted almost entirely to a consideration of the strength of flat plates supported with screwed stud stays such as are employed in boiler construction, and the general tenor of the memorandum is to show that the strength of such flat plates is not in accordance with the Board of Trade formulæ which is usually relied upon in determining the scantlings to be allowed for flat surfaces for steam boilers.

Mr. Stromeyer also comments on what he describes as "the very unsatisfactory nature of the Board of Trade reports on boiler explosions. One reason for this," he remarks, "seems to be the practice of giving each Board of Trade surveyor a turn at conducting an enquiry. Little is gained by the present system," asserts Mr. Stromeyer, "but much time and money is wasted. Surely with about 100 explosions per annum sufficient work could be found for one man possessed of a good college training and suitable practical experience to investigate these cases and to report on them with such clearness that formal enquiries need not be held; or if an occasional one were found to be necessary, he would be the most fitting man to conduct it.

"The money which would thus be saved on expensive formal enquiries, amounting probably to £3,000 or £4,000, might very advantageously be spent by the expert who makes the enquiries on occasional interesting tests, for these are very badly wanted in this country. To a certain extent," he adds, "this is actually being done under difficulties in Germany. There accidents sometimes occur which cannot be entirely explained by the Chief Engineer of the Boiler Inspection Association who conducts the enquiry, but very often he induces some one, generally the manufacturer, to have experiments made. Thus it is that we have to turn to German publications not only for the latest, but for the only, information about the elasticity of corrugated furnaces, the elasticity of steam-pipe bends, the strength of dished ends, &c., and largely also about stayed flat plates."

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1912.

Turning lathes. Popella. 20170.
Internal combustion engines. Wright. 22302.
Manufacture of tungsten. Gladitz. 27859.
Motive power installation, particularly applicable for use in torpedoes, and submarine vessels. Jensen (Dodd). 27981.

1913.

Automatic couplings for railway vehicles. Sokolowski & Morzycki. 60.
Method of and apparatus for heating and purifying water. Tikhomiroff. 131.
Carburetters for internal combustion engines. Doué. 167.
Furnaces for heating moulds. Ferman, and Ferman & Co. 172.
Apparatus for compressing gas. Kilburn. 207.
Speed indicating apparatus. Faigle. 235.
Exhaust silencers for internal combustion engines. Rieusset and Dew. 265.
Vaporisers. Ensign. 280.
Liquid change speed gear. Schiesari. 463.
Internal combustion engines. Sefton-Jones. 510.
Steam turbines. Haddan. 614.
Safety devices for steam-condensing plants. Muller. 692.
Marine turbine installations. Parsons, Cook, & Chapman. 801.
Explosion engines. Daimler Motoren Ges. 812.
Silencers for internal combustion engines. Hutton. 830.
Mechanism for operating the valves of internal combustion engines. John I. Thornycroft & Co., and Bibby. 836.
Valves of fluid pressure engines. Carson. 858.
Exhaust scavenger and silencer for internal combustion engines. Davies. 928.
Turbine compressor installations. Parsons, Cook, & Carnegie. 953.
Steam boiler furnaces. Buckley & Smith. 1639.
Valves for internal combustion engines. Cook & Shippey. 2073.
Instruments for measuring the flow of fluid through a conduit. British Thomson Houston Company. 2417.
Flexible couplings and flexible shafts. Swan. 2634.
Variable speed gear for motor road vehicles. Chamberlain. 2907.
Water circulators for steam boilers. Blizzard, Cotton, & Todd. 3073.
Construction of milling tools. Charlier. 3921.
Centrifugal blowers. Homersham & Berk. 4081.
Methods and means for softening water. Wheaton. 4188.
Apparatus for drilling and connecting branch mains under pressure. Boyle. 4894.
Valves for fluid pressure. Fallot Incandescent Light Company, and Lowe. 5059.
Valves for pneumatic hammers. Daw & Daw. 5613.
Ignition apparatus for internal-combustion engines. Mellersh-Jackson. 6176.
Punching and riveting machines. Dolcher. 7217.
Internal-combustion engines. Vorreiter. 7587.
Rotary blowers. Axien. 8251.
Friction gearing. Carey, and R. Waygood & Co. 9236.
Atomisers for liquid fuel. Soc. Anon. des Etablissements Delaunay-Belleville. 9280.
Punches and dies. Hartog. 9494.
Annealing of wire. Woods. 10215.
Change-speed gears. J. S. Willway & Sons, Ltd., and Moore. 10523.
Supply of air to internal-combustion engines. Heyl & Baker. 11468.
"Chills" employed for hardening and toughening cast metal cylinders. Wheldon & Hans. 11703.
Continuous weighing apparatus. W. & T. Avery, Ltd., and Parnall. 11913.
Fastener for driving belts. Hubbard & Yates. 12398.
Chain belts. Feuge-Renforth. 13338.
Apparatus for manufacturing wood gas and by products. Poole. 13929.
Engine starting and lighting equipment for motor vehicles. Lucas and Turner. 13980.
Method and apparatus for utilisation of residual heat by means of cold vapour turbine plant. Semmler. 14457.
Pipe couplings. Dies. 14944.
Manufacture of chains. Andreas Daub. 15160.
Rotary power engines. Statax Engine Company, Hansen, and Gregory. 15490.
Process of soldering iron and steel. Morosi. 15930.
Rotary engine valves. Spencer. 16209.
Explosion turbines. Pichard & Pichard. 16561.
Smith's forges. Schar. 17027.
Speed indicating instruments. Cash. 17401.
Solar boilers. Keun. 18998.
Pressure and vacuum relief valve. Crompton. 19604.
Automatic train stopping devices. Elliott & Elliott. 20553.
Gas producers. Pierson, and Soc. J. & O. G. Pierson. 21553.
Construction of boilers. Pollak. 21957.
Railway signalling systems. Soc. Anon. Westinghouse. 22029.
Nut locks. Fiehler. 22531.
Safety signalling and controlling devices for railways. Cooper. 22829.
Ball bearings. Hoffmann. 28051.

ELECTRICAL, 1912.

Resistances for electrical heating apparatus. Bastian. 8111.
Switching devices for mercury vapour lamps. Johnson. 27956.

1913.

Apparatus for electrically operating planing machines. Lancashire Dynamo and Motor Company, Wood & McLeod. 13.
Resonating relays. Von Kramer & Kapp. 444.
Automatic telegraph transmitters. Withers. 791.
Automatic telephone exchange systems. Western Electric Company. 1223.
Spark plugs. Duffy. 1281.
Electric contact makers. Clempson & Murrell. 2361.
Regulators for dynamos. Johnstone & Ferguson. 5158.
Electric arc lamps for projection. Schmidt. 5199.
Combined dynamos and governors. Churchward. 7146.
Control of high-frequency alternating currents. British Thomson-Houston Company. 7151.
Reversing and controlling gear for electric motors. Etchells, Congdon, & Muir, Ltd., and Muir. 10511.
Electric elevator systems. Fraser. 13447.
Incandescent electric lamp filaments. Read. 13695.
Electric safety lamps. Faerber. 16058.
Electric incandescent lamps. Read. 16770.
Controlling gear for electrically driven hydraulic pumps. Towler. 16807.
Circuit arrangements for telephone installations with semi automatic working. Siemens & Halske Akt.-Ges. 24459.

METAL QUOTATIONS.

TUESDAY, JANUARY 27TH.

Aluminium ingot	90/- per cwt.
,, wire, according to sizes, &c. ......from	117/- ,,
,, sheets ,, ,, ... ,,	112/- ,,
Antimony	£28/-/- to £30/-/- per ton.
Brass, rolled	7⅜d. per lb.
,, tubes (brazed)	9¼d. ,,
,, ,, (solid drawn)	8⅜d. ,,
,, ,, wire	7¼d. ,,
Copper, Standard	£65/12/6 per ton.
Iron, Cleveland	50/7½ ,,
,, Scotch	56/7½ ,,
Lead, English	£20/5/- ,,
,, Foreign (soft)	£20/2/6 ,,
Mica (in original cases), small	6d. to 3/- per lb.
,, ,, ,, medium	3/6 to 6/- ,,
,, ,, ,, large	7/6 to 11/- ,,
Quicksilver	£7/10/- per bottle
Silver	26¾d. per oz.
Spelter	£21/10/- per ton.
Tin, block	£180/10/- ,,
Tin plates	13/- ,,
Zinc sheets (Silesian)	£25/-/- ,,
,, (Stettin; Vieille Montagne)	£25/2/6 ,,

Explosions in Mines.—The Explosions in Mines Committee have submitted to the Home Secretary the fifth report on the results of their experimental work at Eskmeals Station, in which they make recommendations as to means for preventing coal-dust ignitions. The Home Secretary, in an official communication, states it will be necessary to embody the recommendations in statutory regulations under the Coal Mines Act. He points out that the committee have not recommended the adoption of stone dusting to the exclusion of watering, but adds that it is generally recognised that any system of watering which did not render inert the dust, not only on the floor but on the supports and sides, would not be equivalent to a system of stone dusting recommended by the committee.

The Mechanical Engineer.

AN ILLUSTRATED WEEKLY JOURNAL Vol. 33, No. 837

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Telegrams: "Scientific," Manchester.
Telephone No. 6655 City.

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Boiler Explosions and Board of Trade Enquiries.

In his Annual Memorandum for the year 1912, just issued, Mr. Stromeyer, the chief engineer of the Manchester Steam Users' Association, criticises some features of the reports issued by the Board of Trade on formal enquiries held under the Boiler Explosions Act, and particularly their lack of technical information, which would often be of value to engineers in dealing with questions of boiler design. Without seeking in any way to belittle the good work done by the Act, or the exemplary character of the judgments of formal enquiries as a rule, there is, we think, considerable justification for this criticism. One reason assigned by Mr. Stromeyer for the paucity of technical information is the seeming "practice of giving each Board of Trade surveyor a turn at conducting an enquiry." There is no doubt something in this, for engineers, like everyone else, become more or less expert with practice, and an engineer accustomed to these investigations will immediately size up the salient facts and point the lessons they convey, whereas another, without this experience, might be confused by a contemplation of the mass of wreckage and so fail to extract their true significance. Another and more important reason however, in our opinion, is that where formal enquiries are held the court very often appears to be more concerned with questions of legal responsibility and orders as to questions of costs than with the technical aspects of the case. This is due, we think, to the fact that the court, which consists of a barrister and an engineer, is invariably presided over by the legal member, who, however capable he may be in sifting evidence and deciding legal points, cannot, in the nature of things, possess that scientific or engineering knowledge which is occasionally desirable in analysing some of the technical questions at issue. It may, of course be argued that it is not the duty of the Board of

Trade under the Act to make investigations into structural strengths of the nature suggested, but into the causes of the disaster and to fix responsibility for it on the right shoulders. This may be true, but it is no reason why official public enquiries should not contribute as much as possible to our stock of knowledge, especially when this can be done, as it often can, without entailing extra expense. The information is often available, but in the report has to yield place to a great extent to long wearisome details of evidence. It sometimes happens, too, in these formal reports, that although valuable technical evidence is presented the engineer-surveyor presenting it gets little credit, although he may have been the chief means of elucidating the cause of the disaster. The natural result is that he feels little disposition to make the personal efforts required to piece up the little bits of evidence or pursuing enquiries which the disaster suggests, and which would be of value in settling obscure questions of structural strength. That feeling of this kind has operated we know, and obviously it is not to the public advantage. Mr. Stromeyer suggests that a better course would be for the Board of Trade to appoint "one man possessed of a good college training and suitable practical experience to investigate these cases, and to report on them with such clearness that formal enquiries need not be held, or if an occasional one was found to be necessary he would be the most fitting man to conduct it." As regards special technical investigations, where these would be of advantage the matter does, to some extent rest with the Board of Trade, since it could be given in the report of the "preliminary" enquiry, which is held in every case, but which report is now smothered or compressed into a small space when a "formal" is ordered, apparently to make room for detailed accounts of the evidence of the various witnesses and the summing of it up by the barrister who presides. From the engineering point of view "formal" enquiries might well be dispensed with, and the reports issued restricted to "preliminary" enquiries held by engineers on the Board of Trade staff. Some of the most valuable reports that have been issued have, in fact, been of this kind. The chief advantage of formal enquiries is that the Commissioners who hold them have the power to inflict all or a portion of the costs of such enquiry upon defaulting parties, and thus secure a publicity and exercise a salutary influence on boiler owners and inspectors generally which the engineer who holds the "preliminary" enquiry can not, since he does not possess this power, and how far it would be desirable for this to be delegated to one man, a Board of Trade official, as suggested by Mr. Stromeyer, is a question on which there may be different opinions. We quite agree with him, however, that the engineers who hold enquiries into boiler failures should have had a good scientific training, and that investigators should be limited to one or two men, so that they may become experts, and in this way realise as far as possible the opportunity for acquiring the special information which such enquiries provide. The engineer Commissioner at any formal enquiries should be one of this select staff, and notwithstanding all the traditions of the legal profession he should be president of the court seeing that the questions presented are technical rather than legal. The authors of the Boiler Explosions Act, we may add, and we speak from personal knowledge, desired to make this arrangement, and the substitution of a lawyer for an engineer was only done to allay the opposition which they were authoritatively informed when the Act was passing through Parliament would inevitably be raised if this sop was not offered to the legal fraternity in the House of Commons. The incident was illuminating at the time, and is not without interest at the present moment when legislation bearing on technical matters is brought forward.

There are two other points in connection with these Board of Trade Reports to which Mr. Stromeyer did not refer, but to which we should like to call attention. One is the whimsical manner, or so it seems to outsiders, in which cases are selected for which formal enquiries are ordered. The intention of the authors of the Boiler Explosions Act was that such enquiries should be held whenever flagrant negligence or recklessness was discovered at the "preliminary" enquiry, so that the formal court with its greater powers and publicity might inflict pecuniary punishment and more thoroughly expose defaults. Now it appears to those who are familiar with the subject and carefully peruse the reports issued, that in some cases in which "preliminary enquiries" are held and great negligence is revealed, no "formal" enquiry follows, while in others "formal enquiries" are held when it seems that a "preliminary" would have sufficed. It may be that a fuller knowledge of the facts would cause us to change our opinion, but we may add it is not ours alone, and the irregularity of selection almost suggests that it is sometimes determined rather by considerations of personal convenience than by a strict reference to the importance of the explosion. The second point is the unreasonably long interval that often elapses not only between the occurrence of an explosion and the publication of the report, but between its occurrence and the holding of the "formal" enquiry. Take one of the most recent reports, formal enquiry No. 2,250, referring to the explosion of a heating apparatus, as a sample. The facts of the case were very simple, and yet, although the explosion occurred on February 14th last year, the formal enquiry with regard to it was not held until October 23rd, and the report was not published until December. What is the reason for this delay? Were the facts very difficult to get at and could not the Board of Trade make up its mind? Or was the enquiry deferred to suit the personal convenience of the Commissioners? We can certainly find no justification for these lengthy delays in the report itself, and in its absence the public have a right to complain.

IMPROVEMENTS IN GEAR-CUTTING MACHINES.

SEVERAL improvements in gear-cutting machines of the type in which cutting tools, operating simultaneously on both sides of a tooth, are reciprocated on automatically adjusting or opening and closing guide arms in lines or paths always directed towards the apex of the pitch cone of the wheel, have been devised and patented by Messrs. Smith & Coventry, Ltd., Gresley Ironworks, Salford. They comprise the combination with the guide arms on which the cutting tools are reciprocated, of a dummy or former, having two surfaces of correct configuration, adapted to act upon the guide arms and to be traversed through an adjustable distance.

Fig. 1 is a front elevation and Fig. 2 an end elevation of part of a gear-cutting machine embodying the improvements. The guide arms A in which the tool slides are traversed are arranged in the usual manner and are pivoted about a point which is the apex of the pitch cone of the bevel wheels being cut. Each of these arms has a slot B therein at its free end and a scale thereon, a bracket C being adapted to be fixed in the slot at a certain position indicated on the scale according to the pitch of the wheel being cut. Each bracket carries a roller D which bears upon a surface of involute configuration of a dummy or former E. Thus one roller bears upon the upper and one upon the lower side of the former. The

latter is mounted upon a slide F, which is traversed or reciprocated by means of the quadrant G connecting rod H and arm J, which synchronise in their movements with the feed movements given to the blank during the cutting operations. The rate of movement and length of traverse of the slide F may be adjusted by varying the position of the end of the rod H in the arm J so that the rollers D may traverse a greater

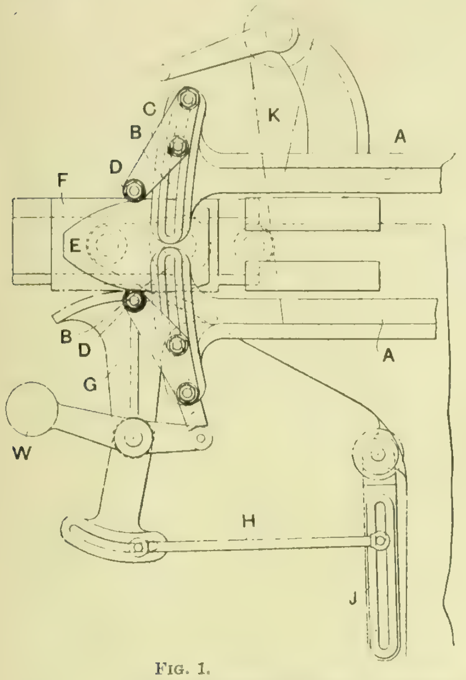


Fig. 1.

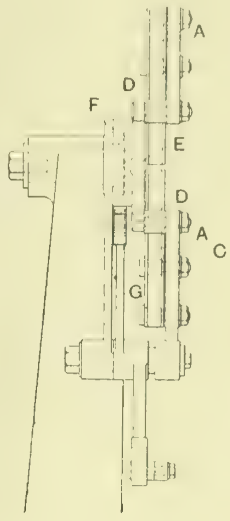


Fig. 2.

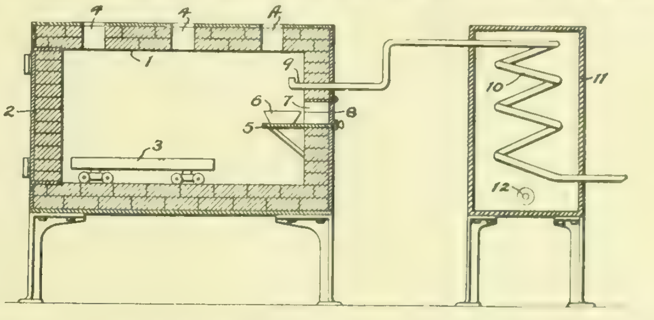
Improvements in Gear-cutting Machines.

or less portion of the former surface during the cutting of a complete tooth and thus the angular distance through which the guide arms A are moved be increased or diminished to suit the pitch of tooth and its corresponding curvature.

In operation, when, for example, a mitre wheel of a certain tooth pitch is being cut, the blank axis is set at an angle of 45° to the path of the cutting tools. The feeler brackets C in the guide arms A are adjusted in position to suit the tooth pitch, and the rollers D each contact with the former at a point on the pitch line of the dummy. The parts being now locked in position, all movements of the blank saddle are communicated to the former. To provide for the correct formation of teeth in bevels of varying angles, the distance through which the former E is traversed during each stroke of the cutting tools is adjusted so that a more or less extended portion of the former is traversed by the rollers contacting therewith. This arrangement provides for a variation in the total angular movement imparted to the guide arms A and therefore a variation in the starting and finishing positions of the cutting tool in the involute path. A counterweight W is provided, which tends to press the lower feeler bracket C upwards. The effective weight of this counterweight is made twice the weight of bracket C and roller D thereon. Thus when the two brackets are freed from the guide arms A for setting purposes, the pressure of the upper bracket upon the former will be exactly the same as the pressure of the lower bracket thereon. The guide arms A are balanced against one another by means of a steel band K, and when the machine is in operation the two brackets balance one another, the pressure upon the two surfaces of the former E being that of the counterweight W only. An adjustable spring is preferably provided whereby the one guide arm is caused to counterbalance the other, so as to allow for variations in length due to expansion or contraction, and to give equal pressure upon the two sides of the former. With the arrangement described bevel gears of any angle or ratio can be accurately cut, and likewise by varying the shape of the former, teeth having different pressure angles of any ratio can be generated. Further, as the former is traversed by copying rollers D, the cutting operation may be accurately performed by round-nosed tools having a radius proportional to the radius of the copying rollers and to the distance of the tool from the apex of the pitch cone when cutting.

PRODUCING A BLACK, RUST-PROOF COATING ON IRON AND STEEL.

A modification of the Bower Barff process for producing a black, rust proof coating on iron or steel has recently been patented by William R. Swan, of the Bontemps Rust Proofing Company, of Bridgeport, Conn. With this process it is claimed that a permanent black finish is produced on iron and steel which is rust-resisting under various atmospheric conditions and the ordinary conditions of use; and further that the process does not require numerous and repeated treatments of the metal, only a few minutes of time being expended, whereas those processes now in common use require from two to eight hours. The apparatus for carrying out the process comprises a muffle furnace and a superheater, and is shown in vertical section in the accompanying illustration. The iron or steel articles upon which it is desired to produce the permanent black finish are first placed in the muffle furnace, together with a quantity of copper sulphate, sal-ammoniac or aluminium chloride, tannin, and glucose. These materials may be placed in the furnace in any manner, as a mixture in a single tray, and any suitable proportion of them may be employed. The inventor has found by experiment that the materials can be advantageously used



Muffle and Superheater for Producing Black Finish on Iron or Steel.

in an ordinary muffle furnace in the following proportions: Copper sulphate five-sixth part, sal-ammoniac one-thirty-sixth part, tannin one-eighteenth part, glucose one-twelfth part.

The iron or steel articles, together with the mixture, which have been placed in the muffle furnace, are heated to about 1,050° Fah. and superheated steam injected into the furnace for a period of about 30 min. The steam for this purpose may be drawn from an ordinary water steam boiler at about 5lbs. pressure and superheated in any convenient manner. After the iron and steel articles have thus been heated in the muffle furnace and subjected to the action of superheated steam in the presence of the mixture they are withdrawn from the furnace and permitted to cool, after which they are submerged in paraffin oil which has been heated to a temperature of about 150° Fah. The articles which have thus been treated are permitted to dry by exposure to the air, and a dead black rust-resisting coating is thereby provided. The pores of the metal will be opened up as it expands under the action of the heat, and this dead black rust-resisting coating will penetrate into the metal as far as this opening up of the pores will permit. The copper sulphate is a metallic salt, and apparently forms the base on the metal which resists the rust, the other materials producing the finish which, with the warmed paraffin oil, gives the dead black desired. Should a heavier coating be desired, this can be obtained by a repetition of the process, although this is ordinarily not necessary. It is not absolutely necessary to use tannin as an ingredient of the compound, and the tannin may be entirely omitted, if desired, although it has been found that a somewhat better finish is obtained where this ingredient is used.

The Institution of Electrical Engineers.—A meeting of this Institution will be held at Victoria Embankment, London, W.C., on Thursday, the 12th inst., when a paper on "Some Railway Conditions Governing Electrification," by Mr. Roger T. Smith (member), will be read and discussed.

POWER PRODUCTION IN THE UNITED KINGDOM.*

BY EDWARD G. HILLER., M.I.C.E., M.I.M.E.

(Continued from page 104.)

In the iron and steel industries the coal consumption estimates are: 1903, 28 million tons; 1911, 32·1 million tons. Both blastfurnaces and all iron and steel works are included, and the estimate of the fuel covers that for heating and for the production of power. In past years this industry has not been one of the centres of highest economy in power production, the use of non-condensing engines being common, accompanied by low efficiency economically in the auxiliary steam plant, also in some cases boilers of the oldest types were retained in use. Thus, up to a few years ago, the cylindrical externally-fired boiler still continued in use in ironworks long after it had become obsolete in textile factories, and the like. In British ironworks to-day a strong movement towards economy of fuel is to be noted. This movement is generally on the lines of higher steam pressures, together with the use of compound engines and condensing wherever possible. The movement is combined with a more efficient utilisation of the heat of blastfurnace gas. Blastfurnace gas, when properly cleaned, is very suitable for gas engines, and on the Continent of Europe, as well as in the United States of America, it has been largely adopted. In this country its adoption in old works has been on a limited scale, so far as the driving of gas engines is concerned.

In new works, however, this method of utilising the blastfurnace gas is being more generally adopted. Considerations of capital, of course, enter into these matters, and while one method of economical power production may pay very well in a new works, different financial items affect the question of its adoption in old works. In old ironworks economy has been more generally sought for on the lines of low-pressure turbines, utilising the exhaust steam of the engines, combined with central electric stations for driving the auxiliaries, the central stations in some cases being driven by blastfurnace or other available gas, and in other cases by steam. The large slow-moving gas engines of 1,000 i.h.p. and upwards, nearly all of German design, seem to have been much improved by experience, and now appear to operate satisfactorily, but the capital cost, combined with the expense of the necessary gas purification plant, is heavy, which militates against their general adoption, particularly in old works.

The amount of fuel used in gasworks, according to official figures, was in 1903 15 million tons, and in 1911 15·4 million tons. This is the amount of coal carbonised producing combustible gas and coke. The estimate for domestic consumption was: 1903, 32 million tons; 1911, 34·3 million tons. Although not directly connected with power, it is necessary to take account of the enormous domestic consumption, which forms so large a proportion of the total annual consumption of coal in this country. This particular item represents the least efficient of all the ways in which the energy of coal is utilised. The flickering, moving, glowing, open fire is a costly luxury. It is pleasant to look at, and it ventilates rooms, but it is very expensive in the effective heat units utilised in heating the room, and it is a method of heating which could only be practicable in a country where coal is relatively cheap. Probably the amount of coal used for domestic purposes will vary more with the variation of weather and season than is the case with the industrial uses of coal. A hard winter will mean increased use of coal for domestic heating, while mild weather will result in a reduced consumption for this purpose.

In past years there was no information of a definite character available in reference to the total power production of this country. This condition of affairs does not now obtain, as information of a definite character was obtained by the census of production (1907), and is now available. Another census of a similar nature is being carried through in relation to the year 1912. The figures given in the final report of the first census of production of the United Kingdom (1907) show a total horse-power of 10,578,475. (See Fig. 3 and Table I.) These figures relate to the capacity of the engines measured by the horse-power which the engines were built to produce, or in those cases where the engines were indicated, the indicated horse-power at full load.

It would appear that of the total horse-power stated, about one-quarter of this capacity is used for driving dynamos for the production of electrical energy, and about three-quarters of the total for driving machinery directly. Of the electricity generated, about two-thirds was generated in electric light and power stations, the remainder being produced by the users, the largest output being that of the iron and steel trades, which generated rather less than a quarter of the total. A copy of the figures for the year 1907 in the census of production is given in Table I. This table embodies interesting information both as regards the types of engines and other power producers in use, and the nature of the industries in which they are employed. It will be seen that reciprocating steam engines in 1907 produced about nine-tenths of the power, namely, 9,118,818 h.p., out of a total of 10,578,475 h.p. Steam turbines at that time generated, or were installed, of a capacity equal to 530,892 h.p., say, half a million horse-power. The bulk of these turbines were in works included under the heading "public utility service," mainly electric supply undertakings. Internal-combustion engines, including both oil and gas engines, accounted for a total of 680,177 h.p. The trades utilising these engines to the greatest extent were the iron and steel, engineering, and shipbuilding trades. No doubt the large gas engines, using blastfurnace gas, and the like, constitute a large proportion of this power. Apparently in the iron and steel and similar trades the total power capacity of internal-combustion engines is about 10 per cent. of the total steam engine power capacity in those trades. The total water power returned amounted to 177,907 h.p., or about 1 per cent. of the total power capacity.

From the estimates illustrated by Fig. 2 and a comparison of the figures with those on Fig. 3 and Table I., an approximate idea may be obtained of the total amount of coal used in the United Kingdom for power purposes. The total steam power of industry in the United Kingdom for 1907 is shown at 9,649,710 i.h.p. Probably for the year 1911, referred to on Fig. 2, 10,000,000 i.h.p. for the United Kingdom will be a fair estimate of the capacity of steam power in use. On the assumption that this coal is utilised in steam engines using on the average 6lbs. of coal per indicated horse-power per hour and working 2,500 hours a year, this would be equal to 6·7 tons per indicated horse-power per annum, and for 10,000,000 h.p. at this rate 67 million tons would be absorbed. The estimated amounts used for power purposes are included in Fig. 2. The figures given are:—

	Million tons. 1911.
Factories	60·7
Mines	20·5
Iron and steel industries	32·1
Other metal industries	1·1
Bricks, chemicals, &c.	5·7
Total	120·1

On the basis of the foregoing approximate calculation it would appear that of this 120·1 million tons of coal, from 60 to 70 million tons per annum, or rather more than half, were used for the production of power in the principal industries of the country.

Power is one of the most discussed elements of the various industries. This is probably because mechanical power is one feature which the industries have in common. Mechanical power is indeed important to each industry, but in particular industries the efficiency of the processes or machines peculiar to the industry in question is often of more importance financially. The cash importance of the economies of power production varies in different industries. If mechanical power costs 10 per cent. of the total cost of production in any industry, then a saving of 10 per cent in the cost of power will amount to 1 per cent. of the total cost of production. The value of the output of industry in the United

* Paper read before the Manchester Association of Engineers, January 24th, 1914.

Kingdom census of production (1907) was 1,574 million pounds. The power used for this was about 10 million horse-power. On the basis of 6·7 tons of coal per horse-power per annum, and 12s. per ton of coal, this would cost £4 per horse-power per annum, or 40 million pounds per annum for the 10 million horse-power. Forty million pounds is 2½ per cent of the total production of 1,574 million pounds, so that between 2 and 3 per cent. would appear to be the approximate average importance to industry of the fuel cost of power production.

As shown on Fig. 3 and Table I., the great bulk of the power in the United Kingdom is generated by steam boilers and steam engines of various kinds. No official figures are available giving the total number of boilers in this country. From a consideration of the various estimates which have been made from time to time and from his own experience, the author estimates that there are in the United Kingdom 160,000 steam generating boilers apart from railway locomotives, of which in 1911 there were 22,874. As the industries of the country steadily increase in output and in power requirements, so the total power developed tends to increase. This naturally would call for an increased number of steam boilers, but this tendency to increase is, to some extent, checked by the fact that part of the increase of power is provided by gas engines, oil engines, and the like; also by the fact that new boilers when put down are generally of greater power than the old ones, so that a less number of boilers do the same amount of work. Further, by increased economies in the utilisation of fuel, a smaller number of boilers will do the same work. On the whole, therefore, even with an increasing industrial output, the tendency to increase in the total number of boilers will be materially checked.

Fig. 4 shows an estimate of the proportion of different types of boilers in use in the United Kingdom. The figures there shown have been obtained from a classification of the types of boilers insured with the National Boiler and General Insurance Company, Ltd., at the periods marked at the head of each column. These figures give an approximate idea of the proportions in which the boilers of the different classes exist in the country, and also afford some indication of the changes which are taking place in the proportions of boilers in use owing to various causes.

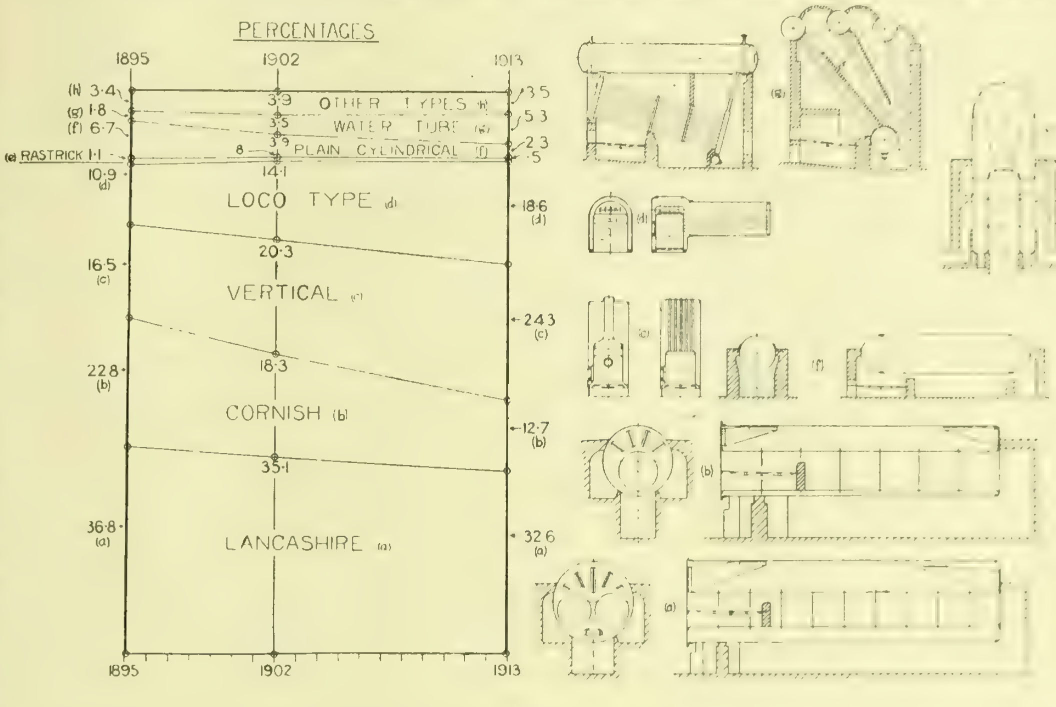


FIG. 4.
Comparison of the numbers of different types of boilers in the United Kingdom, based on the number of boilers insured in 1895, 1902, and 1913 with the National Boiler and General Insurance Company.

The types of steam generating boilers in use in this country are generally less varied than is the case in some foreign countries. For instance, on the Continent of Europe, the variety of types of boilers and combinations of different types, such as combined cylindrical and multitubular, combined multitubular and water-tube, and so on, is much greater than in this country. The general tendency in the United Kingdom has been towards a simplification of type; thus the Lancashire boiler in earlier years was varied with all kinds of arrangements of cross tubes and the like in the flue tubes, and provided with contrivances for circulation, and in the course of years many experiments of variation of form were made. These variations have been dropped, and the present tendency is to adopt a simple form of boiler as indicated at (*a*) on Fig. 4, with plain flue tubes, but no cross tubes, any additional heating surface required being supplied by a superheater in the down-take, together with an economiser.

It is notable also that the externally-fired cylindrical multitubular boiler, the standard low-pressure boiler of the United States, has never obtained any substantial footing in this country. It is a very cheap form of steam generator to produce, but it is subject to serious risks in working; consequently in the United Kingdom all the influences, such as the advice of the boiler insurance companies, have been against this particular type, and have, no doubt, checked or prevented its wide introduction. The proportions of this class of boiler do not exceed 1·5 per cent., and they are included with other types under heading (*h*).

In reference to some of the figures, it is to be noted that the conclusions are subject to the consideration as to what extent the particular class of boiler was insured at the various periods. If the same proportions of boilers were insured at each period, then, of course, the figures will be relatively correct as representing the whole of the country. In the case, however, of vertical boilers, heading (*c*), there is no doubt that an increasing number have come under the inspection of the insurance companies in recent years owing to the operation of legislation, and the figures are rather an indication of this fact than of a general increase in the use of this type.

The Lancashire boiler is the standard type of boiler, and has its home and origin in the Lancashire district. It is still the standard boiler for driving the textile factories of Lancashire and Yorkshire, and is also largely used in collieries, ironworks, and factories generally. It will be seen that the figures show:—

1895	Lancashire	boilers	were	36·8	per cent.
1902	„	„	„	35·1	„ „
1913	„	„	„	32·6	„ „

This indicates a slight relative decrease in the number of boilers of this class. Up to a few years ago, this boiler was considered the standard boiler for all large power installations, but now in the larger electric power stations, water tube boilers are more generally adopted. The latter type of boiler admits of a substantially greater power being placed on the same floor surface as compared with what can be done with the Lancashire boiler, and where good water is available the general tendency towards compactness in power stations results in the preference for the water-tube boiler.

The Lancashire boiler reached its present form of design some years ago, and modern improvements have been only in the direction of details of construction. Up to pressures of 160lbs. it is a very satisfactory boiler for factories with ordinary classes of feed water. As pressures increase above this, difficulties of design and construction arise. The thick plates which it is necessary to adopt for high pressures tend

to stiffness and rigidity, whilst the requirements of the boiler are in the direction of longitudinal elasticity to allow for difference of expansion of the shell and flue tubes. These difficulties frequently make themselves felt by leakages, grooving and fractures about the furnace connections to the end plates, and such difficulties become more accentuated as pressures increase. It is much easier to design a water-tube boiler for a high pressure, such as 200lbs. or 250lbs. per square inch, than to make a satisfactory Lancashire boiler for these pressures. Movements towards high pressures therefore tend to favour the water-tube boiler. The great qualities of the Lancashire boiler which have given it its pre-eminence in past years in all ordinary factories throughout the country are its simplicity and durability, also its suitability for working with ordinary attention and ordinary feed waters. Although in the number of this type the figures show a relative decrease, it is probable that the total power of this type of boiler has increased over the period covered; thus there has been a gradual increase in the size generally adopted for new boilers somewhat as indicated below:—

Sizes of Lancashire Boilers.

1880-1890	Diameter about	7ft. 0in.
	Furnaces	2ft. 9in.
	Grate	33 sq. ft.
1890-1900	Diameter about	8ft. 0in
	Furnaces	3ft. 2in.
	Grate	37 sq. ft.
1900-1910	Diameter about	9ft. 0in
	Furnace diam.	3ft. 7in.
	Grate	43 sq. ft.

The maximum size of Lancashire boilers is determined by the maximum which can be carried on a railway, and 9ft. diam. or a little over seems to reach about the maximum dimensions in this respect. It will be seen from the foregoing figures that this type shows a large relative increase in power per boiler (as measured by grate surface) for the new boilers put down. It is to be observed, however, that in water-tube boilers very much greater increase in power has taken place, thus: In 1890 the power of an ordinary new water-tube boiler would be about equal to one Lancashire boiler, with an evaporation of 5,000lbs. or 6,000lbs. of water per hour, whereas at the present time in various power stations new water-tube boilers are put down equal to an evaporation of four or five Lancashire boilers, evaporating, say, 25,000lbs. to 30,000lbs. of water per hour.

The figures for Cornish boilers show:—

1895	Cornish boilers were	22·8 per cent.
1902	,, ,, ,,	18·3 ,, ,,
1913	,, ,, ,,	12·7 ,, ,,

This shows a substantially decreasing proportion. This type of boiler, as its name indicates, was first introduced in Cornwall for mining purposes, and the type still persists strongly in that district, where batteries of a number of boilers of this type are regularly adopted. In other parts of the country, however, such batteries or groups of boilers of this class are seldom met with. Where larger powers are required, generally a number of Lancashire boilers are put down rather than single-flued or Cornish boilers, and the Cornish boiler is generally used only for such industries where it is desired to have an internally-fired boiler of less power than a Lancashire boiler. The general proportion, therefore, tends to decrease.

The figures for vertical boilers are:—

1895	16·5 per cent
1902	20·3 ,, ,,
1913	24·3 ,, ,,

They include the ordinary vertical boiler with cross tubes in the furnace, also vertical multitubular boilers of various forms, such as the Cochran boiler, &c. The increase shown by the figures for this particular type is in some respects unexpected, for it is well known that in small industries in the larger towns in which small vertical boilers previously were largely used for driving small engines and generally for small power purposes, the places of these small vertical boilers have been largely taken by gas engines and by electric motors with electricity from the town's supply. This particular tendency would be in the direction of a decrease of vertical boilers. On the other hand, steam is being used more generally for all kinds of heating purposes, and in many small industries vertical boilers have been installed for this purpose. Also in this same direction of an increase is the fact that a larger proportion of these boilers have come under inspection in recent years owing to the operation of legislation. The numbers on the whole have increased in such industries as dairies, creameries, laundries, municipal installations such as disinfectors, and various small industries where steam is used for heating. In addition, the Quarries and Mines Act has brought a larger number of these boilers under inspection. On the other hand, the numbers have decreased in various industries where the boilers were employed for the production of small powers.

The figures for boilers of the locomotive type are:—

1895	10·9 per cent.
1902	14·1 ,, ,,
1913	18·6 ,, ,,

These figures show a steady increase. They do not cover locomotives on the main lines of the railways, but include works shunting locomotives, traction engines, road rollers, steam motor wagons, portable locomotives on farms, and fixed locomotive type boilers. The locomotive type boiler is one of the most remarkable of the types in use. Probably if it were to-day presented for the first time nearly all engineers of experience would predict that owing to its complexity and rigidity it could not possibly work satisfactorily. It has, however, given satisfaction in various branches of industry and has become practically the standard type of movable boiler on land. At first designed for railways, it continues practically in the same general form as was settled upon many years ago. For a long time it was the only type in use for traction engines, road rollers, and portable engines, and it now appears to be the predominant type adopted for steam wagons—one of the latest and most vigorous branches of steam power development.

For many years the portable locomotive steam boiler has been the leading form of power producer for farm purposes. Steam boilers on farms are used intermittently, and tend to deteriorate from this cause, and they are not generally under competent inspection. In recent years when farm boilers have been taken out owing to defects, they have been frequently replaced by oil engines. Whether, on the whole, changes of this kind will prove permanent, experience alone can demonstrate. Each of the two types of power production (steam and oil) has its own characteristic advantages. Farm boilers have never come under general inspection, and, therefore, their contribution to the figures under this heading is of an irregular character. The other classes of locomotive boilers, including particularly those used for traction on roads, show a marked increase. The general qualities of this boiler are that it is a fairly economical boiler and is light for its power. The locomotive type is occasionally to be found in use for small powers as a fixed boiler It is, of course, self-contained, and can be worked without any external brickwork flues. The construction is, however, complex, and careful attention to operating, water level, and cleaning is essential, and, generally, the use of this type is not advisable as a fixed boiler, except in special cases where the qualities of this boiler are particularly adapted to the conditions of work.

The figures for the Rastrick type of boiler are:—

1895	1·1
1902	·8
1913	·5

a diminishing and nearly disappearing quantity. This is the iron works boiler which obtained a certain vogue in some districts some years ago for the purpose of utilising the waste heat of gases from puddling furnaces and the like. It proved to be specially adaptable for purposes of this character, but is subject to abnormal risks in working. It is included under a special heading in Fig. 1, not because of its numbers, but in recognition of the great care which it calls for on the part of those responsible for its inspection and supervision. The boiler was used largely with puddling and re-heating fur-

naces. Under these circumstances the external shell plates were subject to the direct impact of gases at a high temperature, leading to bulging, leakage, cracks, and wasting of the plates by oxidation, and, in some cases, sulphur compounds in the gases caused smooth wasting, which was very difficult to detect. In other cases leakage ran down the plates and fostered corrosion under the brickwork, and always there was the objection that the shell, which was in tension, was highly heated.

The one advantage of this type of boiler was its convenience as a working machine; on the other hand, it was full of disadvantages from the point of view of safety, and to-day new boilers of this type are seldom put down. For the purpose of utilising gases from re-heating furnaces and the like, water-tube boilers have been largely adopted, also vertical multitubular boilers, such as those made by Cochran, Davey's, and others. These types are much more satisfactory than the Rastrick type from the point of view of safety, and lend themselves well to the arrangement of furnace connections. Also, two-flued and three-flued horizontal boilers have been used for this purpose, and all of these are preferable to the Rastrick type.

The figures for plain cylindrical boilers are:—

1895	6·7
1902	3·9
1913	2·3

This type is a rapidly decreasing one. It was one of the earliest, as it is one of the simplest forms of steam boiler. Generally its disadvantage is that it is short of heating surface, and the external shell, being heated, is liable to various kinds of defects arising from differences of expansion, contraction, and the like. To overcome the deficiency of heating surface in the old days, increased length was adopted, and with boilers 5ft. 6in. diam., lengths of 50ft. to 70ft. were reached. This great length led to defects and explosions owing to rip at the ring seam. Owing largely to the general realisation of the insecurity of this type in the long form it has become obsolete, and very few new boilers of this description are now being made.

The figures for the water-tube boiler are:—

1895	1·8 per cent.
1902	3·5 „ „
1913	5·3 „ „

These figures show an increasing proportion in point of numbers. If the figures referred to growth of power, the increase shown would be considerably more, because as before mentioned, many of the new water-tube boilers which count only as one boiler have rated evaporations equal to several Lancashire boilers. The water-tube boiler on its introduction here about 30 years ago was regarded as an undesirable class, and certainly the forms such as the Howard boiler were not satisfactory in working. The Babcock & Wilcox type, however, after introduction into this country, was much improved in detail, and proved to have very advantageous qualities in many respects, and other successful types such as the Stirling boiler, the Woodeson, and other varieties have since been produced commercially. The water-tube type has shown in recent years more life and movement in the production of variety and type than other boilers which are generally adopted for the production of power on land.

An important feature of this type is the facility of design for high pressures. Lancashire and Cornish boilers of, say, 160lbs. per square inch, become very stiff owing to the thickness of the plates which it is generally necessary to adopt to meet the requirements of the high pressure, whereas, on the other hand, water-tube boilers with smaller diameter drums and small tubes are easily made suitable for high pressures, without involving the use of such thick plates. Also, the water-tube boiler lends itself very well to the planning of large powers on a limited area, making it practicable to cover a large proportion of the floor with furnace, and obtain further heating surface required by vertical enlargement of the boiler, thus enabling a considerably greater boiler power to be installed on a given floor space than is practicable with the Lancashire boiler.

In the early days there was considerable competition between the Lancashire type of boiler and the water-tube type, both as regards the power development in large electric stations, and also in textile and similar factories. The result of this struggle for position is that in the large electric power stations the use of the water-tube boiler is general, and in the textile and similar factories the Lancashire boiler has retained its position. Water-tube boilers have also been largely applied to utilisation of the heat of gases from reheating furnaces and the like. One special feature of this boiler is that a good feed water is required. Dirty feed water soon leads to serious results owing to the small tubes, and in the early days of the use of this boiler, many cases of overheating due to this cause occurred. Corrosive water also is very objectionable in such small tubes.

Pressures have increased as the result of the search for economy. The advantage of utilising steam at high pressure was recognised at a very early stage by Trevithick, who constructed boilers to work at high pressures, but owing to the imperfection of boiler materials then available and other difficulties in connection with the utilisation of the steam, the experiment failed. The adoption of higher pressures was made practicable as improvements were made in materials and workmanship, and the increase in the maximum working pressures of steam boilers has been in the nature of a gradual increase extending over many years. Considerations of economy in fuel have generally tended to encourage such increase, while increased cost of construction and maintenance have generally tended to check unduly rapid growth.

Fig. 5 shows the gradual increase in the maximum pressures for which land boilers have been constructed at the

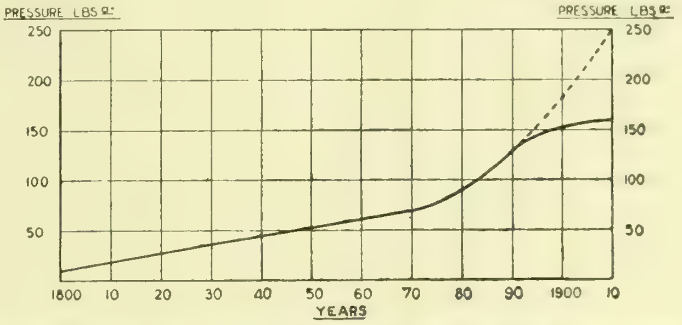


Fig. 5. Diagram showing the Maximum Steam Pressures generally adopted in New Boilers in the United Kingdom.

periods indicated. In the earlier stages, up to about 1830, the low pressures of 6lbs. to 12lbs. per square inch adopted in the steam engines of the Watt type were the ruling pressures. From about 1830 the use of higher pressure, with expansive working of the steam, became more general. A strong movement in the upward direction showed itself from 1870 onwards, when the construction of boilers for higher pressures had been improved by the adoption of steel plates, drilling rivet holes, machine riveting, and flanged seams for flue tubes.

The lower line on Fig. 5 indicates approximately the steam pressures generally adopted from this period onward in the case of Lancashire boilers for textile factories and the like. From about 1880 is to be dated the practical introduction of the modern water-tube boiler, and the upper line on Fig. 5 may be taken as broadly indicating the trend of the maximum pressures in the case of water-tube boilers, as adopted for electric power stations. 160lbs. per square inch or thereabouts seems to be the pressure which has commended itself to those using steam in textile factories and the like, and gives economic results which are good, having regard to the capital cost of the various appliances used, such as boiler, economiser, superheater, engine, and the prices of available coal. With higher priced coal, a higher pressure of steam might be economically advisable, but, with a higher pressure, maintenance charges increase, and the working considerations on the whole, therefore, tend to regulate the increase of pressure to such a figure as is found to give broadly economical results.

(To be continued.)

DYNAMOMETER CAR FOR THE ERIE RAILROAD.

THE mechanical department of the Erie Railroad has recently completed and placed in service a dynamometer car, a general plan of which is shown in Fig. 1. The car is provided with a possible pull or shock registering capacity of 1,000,000lbs., and among other features, incorporates a means of recording locomotive data while the engine is standing still. This is accomplished by means of a supplementary record 4in. wide; the roll being motor-driven during periods when the car is standing and when motion from the axle-drive mechanism is, on that account, not available. Special provision for night running is made by placing hoods for searchlights at the floor level on either side of the car.

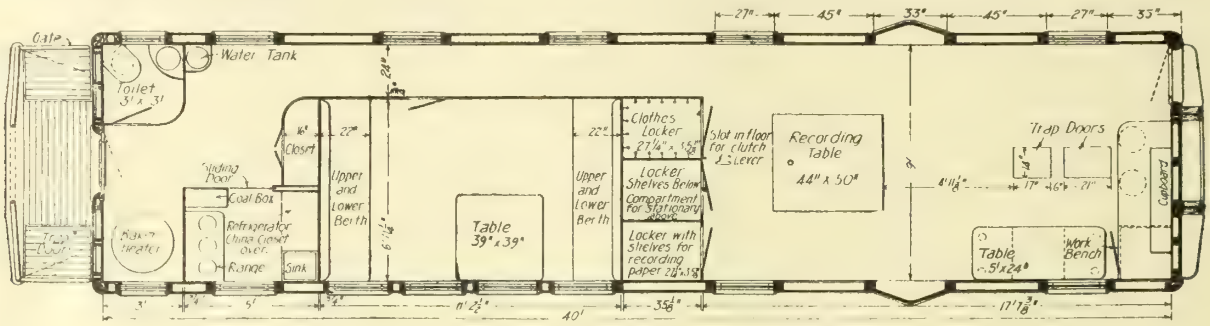


FIG. 1.—GENERAL PLAN OF DYNAMOMETER CAR, ERIE RAILROAD.

The dynamometer is of the liquid type with double pistons 20in. diam., whose heads press against blind rubber gaskets covering the liquid cylinders, from one of which the pressure of the draw bar pull is registered, the other the buffing. The pistons have $\frac{1}{64}$in. clearance and move on ball bearings, and the arrangement is so designed that the pull or buff delivered at the coupler acts in a direct line on the dynamometer; the rubber gaskets doing away with piston fits or packing in such a way as to make the dynamometer practically frictionless. The pressure in the dynamometer cylinders (alcohol being used) is transmitted through extra heavy steel pipes to the recording table. The dynamometer apparatus is similar in principle to that installed on a car for the Atchison, Topeka, and Santa Fe Railway, and described with illustrations in the "Mechanical Engineer," July 26th, 1912 (see p. 92, Vol. XXX.).

The liquid pressure from the dynamometer is directed against the recording cylinder pistons which work against carefully calibrated springs connected to the recording arm. A combination of different springs and pistons at this point is used such as will give an 8in. maximum movement of the recording arm each side of its central or neutral position; one side of the centre registering buffing forces, the other indicating drawbar pull. By changing the combination of the springs and pistons, a registering capacity can be had to any desired amount up to 1,000,000lbs. on the drawbar.

The dynamometer chart is driven either by an axle drive or by a motor. Two rolls of paper are used; one being a 30in. roll on which records are made when the car is under way, the other being a roll on which data is registered when the train is at stop, such as variations of steam pressure, coal fired, strokes of air pump, time of detentions, &c. The record may be driven at a rate of 13·2in., 26·4in., or 52·8in. per mile by the axle drive, or 6in., 12in., or 24in. per mile by means of the motor drive. The following records are made on the dynamometer chart: Drawbar pull; drawbar buffing; train line pressure; strokes of air pump; location; position of reverse lever; position of throttle lever; variations in steam pressure; record of indicator cards; coal fired; time injector is used; and time safety valves are open. The seven last-named items are registered by an observer in the engine cab. By the use of a telegraph key, in the handle of which is a plugging system, he may readily connect each of nine separate conductors to one side of the key, the opposite side being connected to the common conductor. A 10-conductor extra flexible cable is used between the engine cab and the car, at the end of which is connected a train line coupler plug which can be plugged into a coupler socket at either end with connections to the recording table magnets which are actuated by the contact of the telegraph key. For convenience a telephone system is also used between the engine cab and the car.

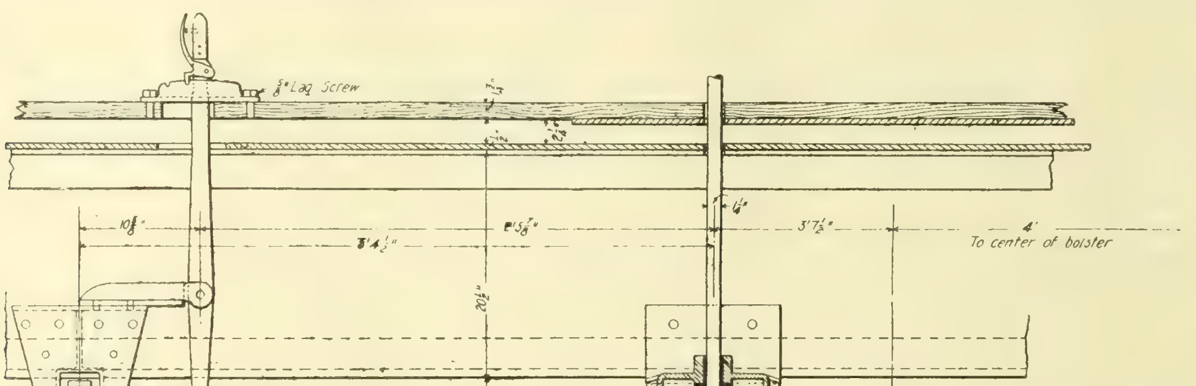


FIG. 2. TRANSMISSION APPARATUS FOR RECORDING PAPER. DYNAMOMETER CAR FOR THE ERIE RAILROAD.

All curves and lines are drawn on the chart by means of specially-constructed pens made for the purpose, which are attached to hollow aluminium rods running at right angles to the chart. The pens are small brass cups with phosphor-bronze troughs which, with a thread wick from barrel to point, are very satisfactory in performing their work, marking plain thin lines when operating in any direction. The train line pressure is transmitted to an indicator, similar to the standard outside spring Crosby indicator specially built by the Crosby company to register on the recording chart by a curved line relative to a datum line at zero. The time and speed record is

drawn on both extreme edges of the chart by means of pens connected to a small electro magnet, which in turn is actuated by electric contact made at six-second intervals by an electric contact time clock. The record of location is made by an observer from the cupola of the car, by the use of a push button connected to one of the electro magnets on the recording table. The observer is also provided with an electric searchlight to assist in taking observations at night.

The recording room in the dynamometer end of the car is 17ft. 7⅜in. long and 9ft. wide, containing the recording apparatus, switchboards, pressure gauges, clocks, work bench, cupboards, &c., with a cupola to assist the operators in taking observation. In the centre of the car is a stateroom, 11ft. 2½in. by 6ft. 11¼in., containing two upper and two lower berths. The rear end of the car contains a Baker heater, the toilet room, and the kitchen with its range, refrigerator, sink, and cupboards. The underframe is of the built-up type, consisting of web plates, cover plates and angles, with pressed-steel transoms and built-up bolsters. A Cardwell friction draught gear is used on the platform end of the car with a high capacity buffing arrangement. On the dynamometer end of the car a Westinghouse friction draught gear is used. The underframe is intended to have a shock resisting capacity of 1,000,000lbs. The trucks have cast-steel frames, bolsters, and spring planks, designed with special clearances to accommodate the dynamometer apparatus. The car is equipped with a 32-volt car-lighting system. The switchboard contains a standard car-lighting control system and an auxiliary switchboard arranged with a series of multiple jacks in such a way that 8, 16, 24, or 32 volts can be used on any of the electric connections on the recording table. We are indebted to the "Railway Review" for the accompanying illustrations and particulars of this car.

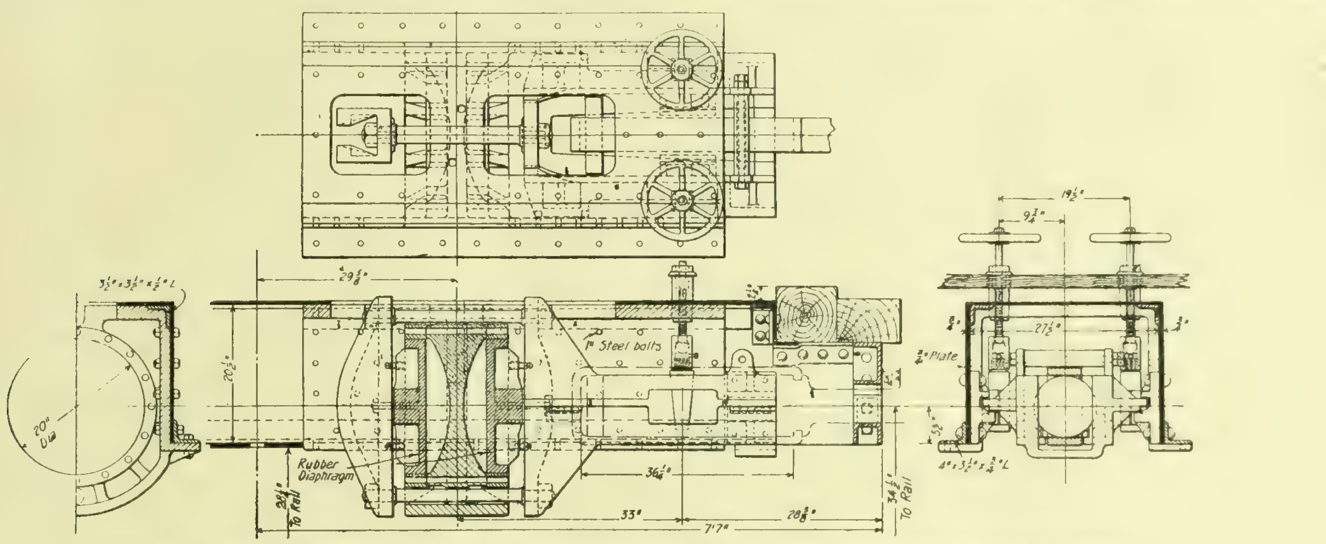


FIG. 3.—ARRANGEMENT OF PRESSURE HEAD AND DRAUGHT APPARATUS. DYNAMOMETER CAR FOR THE ERIE RAILROAD.

ELECTRIC TRAIN LIGHTING SYSTEMS.

IN the course of a paper read before the Institution of Electrical Engineers, Mr. T. Ferguson described a number of systems now available for the electric lighting of trains. Railways had, he said, been slow in adopting electric lighting for their passenger stock, but he considered that this reluctance could hardly be for the reason that it was unsatisfactory as a means of illumination or that there was no reliable system available, as there were many perfectly reliable electric-lighting systems on the market. It would appear that the reason why electricity at the present date had not entirely superseded gas was one of capital expenditure. When electric lighting was first introduced, some 20 years ago, it found lighting by compressed oil-gas already in total possession of the field, except in some few instances where lighting by oil lamps was still in vogue. The gas-lighting plant installed represented a very large capital invested in gas-works, compressing stations, travelling gas tanks for charging the gas cylinders of trains in outlying districts, and also, of course, the storage cylinders and general installations on the carriages themselves. If all this were done away with and electric lighting took its place, obviously the cheapest system would be to install high-speed steam-driven generators on the locomotives and merely equip the carriages with lamps and wiring, providing suitable cable connections between the carriages. This system was used to a limited extent in America, where it was known as the "head end" system. Though certainly the cheapest in first cost and subsequent maintenance, it afforded some inconvenience to traffic working, insomuch as the locomotives must remain attached to their trains for longer periods than were necessary with the gas-lighting system.

The lines upon which electric-lighting systems had been developed were practically confined to the "individual unit" system, where each carriage carried its own generator, driven from the axle, and also a storage battery to supply the lights when the train was standing. The "individual unit" system was particularly well adapted to the requirements of the railways, as each coach so equipped was an independent unit, could be run anywhere on the railway, and had no storage tanks which required to be recharged at frequent intervals. The constant-current and constant-voltage schemes each possessed distinct merits. Judging from the examples at present on the market, it would appear that the constant-current system was by far the more popular; and most of those systems which used a constant voltage or some modification of constant voltage employed a rising characteristic for charging. Even if constant current represented the extreme of this rising voltage characteristic, yet its simplicity, ease of adjustment, independence of fine adjustment, and faculty for desulphating faulty batteries commended it to the practical railway-lighting engineer, who could feel some confidence that, even should the regulation of the dynamo or special regulator become somewhat coarse through unavoidable defects or rough handling, the working of the system would not be very much impaired.

Thrust Bearings.—At a recent meeting of the Institution of Civil Engineers, a paper on "Thrust Bearings" was read by Mr. H. T. Newbigin. The efficiency of a thrust bearing as compared with a journal bearing was pointed out, together with their disadvantages, especially in high-speed machinery. A comparison was made between Coulomb's laws of friction and the late Prof. Osborne Reynolds' hydrodynamic theory of lubrication, and coefficients of friction in bearings of various forms were given. The way in which the friction in a journal bearing changed from dry or greasy friction to perfect lubrication as the speed increased was discussed, and the late Mr. Beauchamp Tower's discovery of liquid pressure in the oil-film was described. Viscosity was defined, and the resulting general formula was compared with the results of Mr. Tower's and Prof. Goodman's experiments. The conditions necessary for the maintenance of liquid pressure in an oil film were examined and defined. The subsequent developments of Reynolds' hydrodynamic theory of lubrication were referred to, and Mr. A. G. M. Michell's formulas for the resistance of lubricated plane surfaces were cited.

BALL BEARINGS.*

BY DAVID MARTIN, A.M.I.E.E.

Ever since the introduction of machinery, the reduction of friction has been the subject of much thought and many inventions. All are acquainted with the numerous attempts, such as the well-known cone-shaped lathe centres, the equally well-known disc wheels, used for the balancing of rotary parts such as flywheels, crank shafts, and latterly the rotors of turbines. Nor must we forget the highly serviceable white metal, and other anti-friction metals used for heavy work, such as we find in marine practice. Rolling motion was early recognised as one of the simplest frictionless (so-called) methods, for it is surmised the early Egyptians adopted that method in moving heavy weights, and it is known that the Romans made use of it also, but the first known record of an attempt to use balls in this connection does not occur till about 1860, when Wm. Fyffe, the engineer to the Crinan Canal, made use of what are now styled ball bearings. No appreciable advance, however, was made till the introduction of the safety bicycle in the early eighties. Primitive as these cone-shaped race ball bearings were, they undoubtedly reduced the pedalling fatigue enormously, and one has only to remember that "fitted with ball bearings" was a selling point in those days. It is questionable if cycling would have reached the enormous proportions it did in the cycle boom period of the early nineties but for ball bearings.

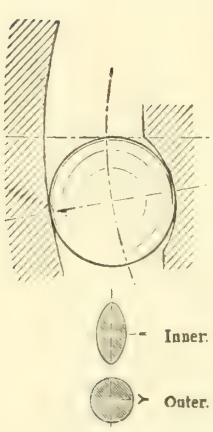


Fig. 1. — Development of Bearing Surface in S.K.F. Self-aligning Bearing.

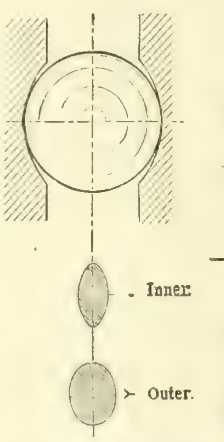


Fig. 2. — Development of Bearing Surface in the Ordinary Single Row Rigid Type.

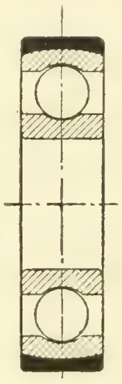


Fig. 3.

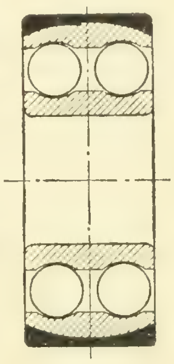


Fig. 4.

Prof. Stribeck carried out a series of investigations to determine the laws governing the design, construction, and application of ball bearings. These investigations proved that, not only would a properly designed ball bearing carry a greater specific load than either roller or plain bearings, at high speeds, but also that the coefficient of friction was enormously reduced—in fact, from something between ·15 and ·2 for metal to metal depending upon the metals, to something between 0·0012 to 0·0018 for balls against enclosing races. At the same time he found that this coefficient of friction varies little through wide ranges of speed and load, as will be seen later. From these investigations, the effective carrying element or load sustaining area A of plain, roller, or ball bearings is expressed by the following formulæ:—

For plain bearings—

$A = L \times D$, when L is the length of the journal, and D its diameter.

For ball bearings—

$A = \frac{D^2 \times N}{5}$, where D is the diameter, and N the number of the balls employed.

It will be noticed he determined that the load-carrying efficiency of a ball varies in proportion to the square of its diameter. It has since been proved that the size of the balls and their speed of rotation must be taken into account, but for comparison purposes this modification may be neglected, and the following conclusions are therefore unaffected by this modification. That is to say, Dr. Stribeck found that the safe load for roller bearings ranges between six and 10; for plain babbited bearings, well worn in, from eight to 20; and for ball bearings of the single row type 10 times the latter figure; while for ball bearings of the double row and staggered type, three times the latter. Ten years ago such a claim was met with considerable scepticism, but in the intervening ten years much has happened, with the result that those who early made use of these scientific experiments have been able to reap the benefit. The marked superiority of ball over roller bearings is explained by the fact that, in the latter, any deformation in the shaft, rollers, or housings, due to elasticity of materials or slight inaccuracies in workmanship, necessarily destroys the theoretical line contact in each roller, causing a tendency to skew, and introducing sliding friction instead of pure rolling motion. With greater accuracy better results might be obtained. With ball bearings of the self-aligning type this sliding friction is in a most practical way eliminated, while accuracy of the most extreme kind is obtained without an increase in the cost of production.

Dr. Stribeck's investigations resolved themselves into what might be termed a specification of an ideal bearing, as follows:—

(1) The steel used in both the balls and the races must meet the most rigid specification as to uniformity, hardness, and tenacity. That is to say, it must be of such a grade that it will temper properly. A comparison of the elastic limits is useful. They are for mild steel 15, and for tempered steel 85 (Prof. Unwin). Therefore, what is now termed "ball bearing steel" should only be used. That obtained in the famous Central Swedish mines has proved to be the best. The low percentage of 0·027 and 0·006 sulphur, and 0·002 to 0·0045 phosphorus, present in this ore, indicates its extreme purity.

Engineers have been accustomed to consider case-hardening as essential for the running surfaces of the races, but experience has proved this to be fallacious as compared with the hardened-tempered race, for the reason that case-hardening tends to flake, and in polishing a case-hardened surface the soft backing is liable to be exposed, leading to dissatisfaction and that want of confidence in ball bearings with which we have so long been associated. Again, once this flaking action commences nothing will stop it, with the result that total destruction of the bearing sooner or later takes place, due to the grinding action set up. This grinding action is further aided, in the case of the single row of ball type bearing, by the unequal contact area exposed to the balls by the outer and inner races, causing a sliding friction on the inner race, as indicated on Figs. 1 and 2. These two faults combined accelerate the inevitable failure.

(2) The second qualification is that the balls must be accurately ground; they must be separated from each other, to prevent contact friction at high speeds; they must be free to revolve in the direction in which they travel, that is, they must give a pure rolling motion; and they must be capable of easy removal and replacement, to facilitate inspection when required. It has been, for some years, easy to grind balls accurately, and to guarantee them perfect within 1/10,000th of an inch.

(3) The third qualification is a most important one, as it relates to the races. These must be accurately ground to standard and interchangeable dimensions. The faces presented to the balls running on them must be absolutely continuous, and free from lateral grooves. They must have such a curvature as will properly retain the balls, and present a uniformly rigid bearing surface for the balls to roll on without shock. Any race of the split variety, therefore, does not comply with this clause. To have a bearing in two halves is certainly easy of installation, but one has only to picture to oneself what takes place in ordinary railway or tramcar working, due to the bumping over rail joints, to get some idea of what takes place with the point contact of balls going over a joint in a race, however good it may be made. In some of the earlier forms they were made split, but failure soon developed. Apart from that, it is a better commercial proposition, on account of the cheaper cost, to have a wholly turned-up-in-the-lathe piece than one in which a considerable amount of time has been spent in fitting by hand. Practice has proved the continuous race to be the ideal.

* Paper read before the Scientific Society of the Royal Technical College.

In many bearings of the single row rigid type, in order that the balls may be got into place, they are threaded through lateral grooves. This type presents the same objection. One cannot guarantee that the balls will roll clear of the grooves under running conditions, and the bumping over the grooving spells failure sooner or later. To obtain a uniformly rigid bearing surface of necessity means that the race must be absolutely circular, which cannot be obtained with the split type however careful the fitting of the two halves may be.

(4) The fourth qualification is also important, in that the complete bearing must be self-contained and easy to install; it

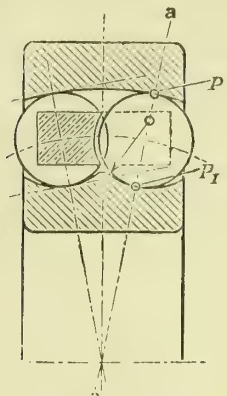


Fig. 5.

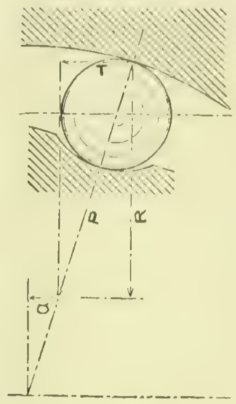


Fig. 6.

must be capable of withstanding axial as well as radial loads; it must not offer any resistance to shaft flexure, and be so designed that the load is sustained by the maximum number of balls. Hardly two men would agree as to exact tightness with which the races and balls should be clamped together, and therefore to ensure success the bearing should be self-contained, and nothing left to chance. Until 1907 no bearing built for pure radial load was made which would stand up to an axial thrust in addition. By reference to Fig. 3 it will be seen the ordinary single row type, having two rings or races and a single row of balls is inflexible, and requires to be mounted with the greatest accuracy to ensure free running. For this reason their use is limited, on account of the great risk of wear and also fear of wedged and broken balls. It is impossible to expect a single row type to take an axial thrust, as the balls would jam, just as they do in the auto-friction clutch which is built on the same principle, namely, a row of balls between tapering surfaces. For the same reason, the arrangement, as shown in Fig. 4, also possesses the same disadvantage.

A reference to Fig. 5 will demonstrate the theory of the S.K.F. type. The radial load on all bearings is taken at right angles to the surfaces in contact, and when these surfaces are sperical, as in ball bearings, it passes through the centre of the sphere. The pressure applied to the outer race is divided equally between the double row of balls, and is balanced by a corresponding pressure reacting from the inner race. This reacting pressure can be divided into two components, one acting at right angles to, and one parallel with the lines of pressure between the ball races. As these pressures are identical from each race, it follows that the whole bearing must be in perfect balance. It will be noted that the tangents of each ball at its point of contact with the races are parallel, and tend to remain parallel, and that lines drawn through the contact points of all balls meet at the centre of the shaft. The plane of rotation of each series of balls is therefore a cone, and provides for the resistance in either direction of axial thrust. By referring to Fig. 6, and reasoning out on the principle of the parallelogram of forces, it is seen that if P is the resultant and R the radial force or load, T will be the axial force or load. That is to say, the more conical a bearing is, the greater the safe-thrust load will be in proportion to the radial, and so on until the radial action disappears, when we have nothing left but a simple thrust, which is provided for by a different shape of bearing termed "thrust washers."

A further reference to the figures also indicates what will happen when shaft deflection or flexure comes on. In the single row type, Figs. 2, 3, and 4, the balls become jammed, leading to extra wear if not fracture of the balls, whereas in the double row type shown, Figs. 1, 5, and 6, the balls simply roll over to the new position without any extra strain being put upon the balls. Many attempts have been made to obtain this ideal self aligning feature, but none so admirably as to get it by a rolling motion of the balls, where friction is a minimum.

An attempt was made to get this self alignability by shaping the outer surface of the outer race to self align on an additional outer race (Figs. 3 and 4), which, of necessity, had to be split in order to suitably house the running race, and by the substitution of two rigid rows of balls. The enormous differences, however, in the frictional coefficients in practice proved that the balls became jammed before the race took up the requisite new alignment. In roller bearings this self-aligning feature is obtained by making the outer races of a spherical shape around their axis and about the centre. In another type the rollers are made of spirally wound steel tapes, which yield to any distortion of the shaft, but the undue strain set up leads to a corresponding increase in friction and wear, as the load is unequally distributed. It is interesting to note that Prof. Goodman, of Leeds University, has come to the same conclusion, as shown in a paper presented to the Institution of Civil Engineers.

The following formula, obtained from the S.K.F. Company, is the result of careful research, and is applicable to all makes of radial type bearings:—

$$P = K \times \frac{Z}{5} \times D^2$$

where P = safe working load in lbs.
K = coefficient.
Z = the number of balls in the bearing.
D = diameter of balls in $\frac{1}{8}$ths inch.

Coefficients.

Revs. per minute	0	10	150	300	500		1000
Coefficient K =	48·4	36·3	29·04	24·2	20·9		15·62
Revs. per minute =	1500	2000	2500	3000	4000	5000	10000
Coefficient K =	13·64	12·1	10·56	9·68	8·58	7·7	5·06

Ball bearings first found favour for industrial purposes in light machinery running at high speeds, such as ventilating fans and small electric motors, and later, for heavy machines running at low speeds, such as lifts and crane hooks. Their true value, however, is now realised, since they have been found suitable for carrying at high speed heavy loads where they are also subject to severe shocks, such as in woodworking machinery, where speeds of 5,000 revs. per minute are common, centrifugal pumps, Diesel engines, and the like. It is of the utmost importance that only the finest steel be used, for the better the material the greater will be the safe load capable of being carried. Further, the greater the number of balls used, the greater the load. Homogeneity and freedom from flaws is absolutely essential. Many of the present-day races are too light, but as the sizes have become standardised, the only thing to be done is to reduce the ball diameter and increase their number. For example, a 30 mm. bore bearing might be fitted with 14 balls $\frac{5}{8}$in. diam., or 30 balls $\frac{7}{16}$in. diam. At a speed of 300 revs. per minute the coefficient K would be 10. Thus for the large balls:—

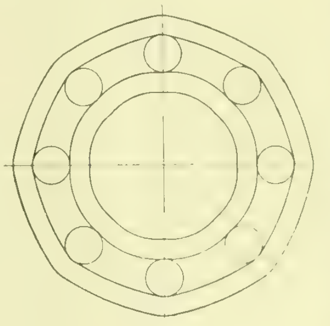


Fig. 7

$$P = 10 \times 5^2 \times \frac{14}{5} = 700 \text{ kgs.}$$

and for the small balls where diameter of balls is again in one eighths of an inch—

$$P = 10 \times 3{\cdot}5^2 \times \frac{30}{5} = 735 \text{ kgs.}$$

The apparent advantage of a large number of small balls is really greater, as the load is distributed over a greater number of points, and if these points are staggered, as in the double-row S.K.F. type, we have, under the worst conditions,

a three-point contact in place of a single point. From experiment, however, it is found that when in work the load is really distributed over the balls (see Fig. 7). If the cage is removed the balls remain stationary, and it is almost impossible to move the balls, but the moment the load is removed the balls fall to the bottom of the race.

Points to remember in using ball bearings:—

(1) Never drive a bearing on to a shaft by a hammer.

(2) Never use lubricant containing acid or alkali.

(3) Never allow a bearing to get rusty

(4) Prevent grit getting between the race and the balls.

(5) Never use a bearing having a split or cracked race.

(6) Never allow a bearing to run dry, although ball bearings only require lubricant two or three times a year. From numerous experiments, and long experience, it is found that 90 per cent. of the lubricant necessary for plain bearings can be saved.

(7) Don't run a ball bearing which tends to become hot, as that is a sure indication that something is wrong. No amount of lubrication will prevent such, and it is safer to consult the makers, giving them full particulars of duty, &c. The effect of temperature rise can be seen from the following table, and the safe working load table requires to be reduced in the following proportion:—

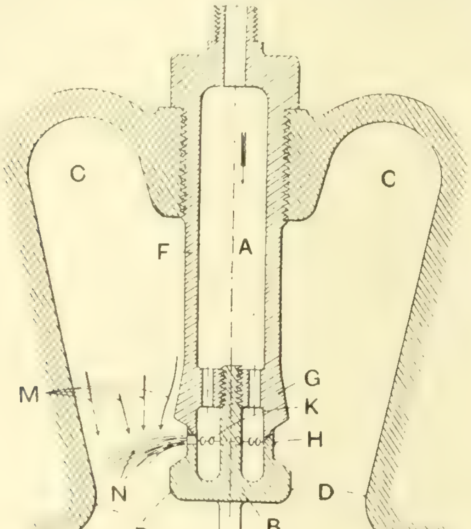
50° C. to 100° C. (122° to 212° Fah.) divide by	1·5
100° C. to 150° C. (212° to 302° Fah.) ,,	2
150° C. to 200° C. (302° to 390° Fah.) ,,	4

No ball bearing should be exposed to any higher temperature than 200° C.

(8) Do not use thrust washer ball bearings for speeds over 2,000 revs. per minute. Use radial type calculated to take the load safely, as they can be run with safety up to 30,000 revs. per minute for 3in. diam., or a peripheral speed of 25,000ft. per minute.

ATOMISER FOR LIQUID FUEL.

THE accompanying illustration shows the construction of a liquid fuel atomiser of the type comprising an air admission nozzle tapering inwardly towards the fuel admission orifices, the invention of Messrs. Delaunay Belleville, of rue de l'Ermitage, St. Denis (Seine), France. The apparatus is more particularly intended for use in connection with generators under pressure in which vaporisation takes place by the mixture of water with the combustion gases such as



ATOMISER FOR LIQUID FUEL.

are used on board self-propelled torpedoes, and usually designated air-heaters. It is equally applicable, however, for use in connection with boilers or furnaces of any type where heavy oils are employed which require to be properly atomised before being supplied to the furnace. The essential features of the device consist in the disposition of a conical flaring provided with skew-backs arranged above a restricted ring in which the fuel admission orifices are formed, a depression being thus created in the hollow ring by the division of the gaseous current owing to the conical flaring. This depression enables the liquid jets to be carried well away from the wall of the atomiser, so that the jets penetrate at a high velocity into the heart of the gaseous current, thus forming a good homogeneous mixture.

Referring to the illustration, the atomiser comprises a hollow cylindrical body A in which the liquid fuel circulates which has been discharged under a pressure slightly higher than that of the air or gas which has to be burnt. The outer wall F, in its upper part cylindrical in shape, tapers outwardly towards its lower part to form a cone at G, thereafter tapering inwardly and being provided with a skew-back. A lower plug B, screwed in the body A and fitted on conically to the skew-back formed on to the part G, has a restricted ring portion H provided with orifices K at right angles or slightly inclined to the axis of the atomiser. These orifices are sufficiently numerous to spray the liquid fuel circularly and their diameters are proportioned with reference to the desired output and the nature of the fuel to be consumed. The carburetting air is driven into the envelope C; this air is displaced in the direction indicated by the arrows M at the lower end of the part C which tapers inwardly in the shape of a converging nozzle D and subsequently spreads out. The cone G causes the deviation of small air currents which descend along the wall, and a zone of reduced pressure is formed thereby within the skew-back H; and under the influence of this reduced pressure zone the liquid jets N passing through the orifices K have their velocity increased, and are projected with greater force through the air which passes through the nozzle D, which favours the dilution of the liquid, its mixture with the air, and finally the formation of a homogeneous gaseous mixture.

THE CARE OF STEAM BOILERS.

AT a recent meeting of the Belfast Association of Engineers, a paper was read by Mr. George Elliott, M.I.M.E., on "Some Infirmities of Steam Boilers," in the course of which he said the "infirmities" of a steam boiler might be described under two headings, namely, "constitutional" and "acquired." The making of a boiler in the early days was a happy-go-lucky or rule-of-thumb business, little or no attention being given to proportioning the different parts; and consequently the badly constructed and worse proportioned boiler was on the "sick list" the greater part of its life. In modern practice, however, more attention was given to material and construction; yet even after every precaution was taken the result might turn out unsatisfactory. The foundation of a good boiler was really laid by the plate makers. He was afraid too much reliance was often placed on the stamp on the plates. Acquired defects were more numerous, and were not so easily dealt with. The most prevalent, and at the same time the most difficult to combat, was the "grooving" of the end plate. It was very erratic in its action and therefore difficult to counteract. The furnace was especially liable to injury from various causes, the most destructive being overheating, caused by shortness of water, due either to carelessness or incompetence. The accumulation of any form of deposit should be particularly guarded against. Continuing, he said no matter what precautions were taken to secure the best material and workmanship, if the boiler fell into the hands of an ignorant owner or attendant it was a source of great danger to its surroundings. The most serious and difficult problem they had to deal with was the incompetence and recklessness of some owners and attendants. The Merchant Shipping Acts had effectively dealt with those men on board ship, and it followed that similar laws to deal with steam-users on shore were required. The first step was to compel every attendant in charge to pass an examination and receive a certificate of competency. The paper was illustrated by a number of lantern slides, and an interesting discussion followed.

Napier Tercentenary Celebration.—John Napier's "Logarithmorum Canonis Mirifici Descriptio" was published in 1614, and it is proposed to celebrate the tercentenary of this great event in the history of mathematics by a congress, to be held in Edinburgh on Friday, July 24th, 1914, and following days. The celebration is being held under the auspices of the Royal Society of Edinburgh.

THE ENGINEERING PROBLEM OF ELECTRIFICATION.*

BY A. H. ARMSTRONG, M.AM.INST.E.E.

THE broad question of whether electrification will show an attractive return upon the large capital investment required can best be determined by a detail investigation of the local conditions obtaining in any given case. Any estimate of a general character is at best more or less misleading when applied to a specific problem. The electric locomotive possesses many operating characteristics not shared by the steam engine, and its introduction opens up possibilities in operating methods that may make it desirable to effect sweeping changes in train operation as now carried on with steam engines. Until one or more engine divisions are electrically operated, what it means to the railway operator to be relieved of many of the limitations of the steam locomotive perhaps may not be fully appreciated.

For example, given an electric locomotive capable of hauling an 800-ton passenger train at 60 miles per hour on level track and, without assisting locomotives, haul the same train up gradients of 2 per cent. at a speed of 25 miles per hour, it is possible to make radical improvements in schedule. When it is considered, furthermore, that such an electric locomotive requires no stops for fuel and water and can operate 1,200 miles or more between inspections, it is evident that electrification calls for considerable readjustment of steam railway traditions.

Failure to fully grasp the possibilities of electrical operation may result in running up the first cost of proposed electrification to an extravagant total upon which no adequate return is possible. So much local colour is required to intelligently discuss the question of "Will it pay to electrify," that no attempt will be made in this paper to discuss the financial aspect of the matter. The several important installations now under construction and even larger projects upon which favourable decision has been reached, all point to the fact that electrification must be attractive in some instances at least. There are, however, certain fundamental data governing the operation of all electric locomotives, and it is the purpose of this paper to discuss some of the engineering questions involved.

At the outset, it is found that the electrical engineer has perfected several types of locomotives and different methods of distributing electric power to them, thus giving rise to what is known as several different "systems of operation." The term "system" is generally applied to the combination of locomotive and trolley or third rail distribution, as the question of power generation and transmission is common to all. While it is true that the single-phase and split-phase locomotives call for a supply of single-phase 25 cycle power, it is only in isolated instances that this kind of electric power can be economically generated and used exclusively by the railway company. Large power installations are now so well equipped to give attractive power rates over extended areas and economical electric power production is so completely an industry in itself, that local conditions must be very favourable to justify the installation of a separate power house devoted exclusively to railway load. Even should such a separate installation be made, it may be considered sound engineering to look to future possibilities and install apparatus similar to that in neighbouring systems where the frequency and voltage are standardised. Different frequencies are not as serious as conflicting track gauges, but they do involve the burden of expense and loss in efficiency of frequency changing sets which it may some day be found expedient to install in order to tie the two systems together. Hence the statement is again made that the generation and transmission of power offers the same problem without regard to the system of electrification favoured.

It is proposed to replace the steam engine with a type of motive power that offers superior advantages in the hauling of heavy trains. In other words, the electric locomotive itself constitutes the main argument in favour of electrification, and no marked excellence of distribution system can offset the failure of the electric motive power. The steam locomotive it is proposed to replace is a highly developed machine of great reliability and the result of the experience born of a great many failures. It cannot be too strongly emphasized, therefore, that the electric motive power is the controlling factor in main line electrification, a point of view that is sometimes overlooked. The three electric systems considered for main line electrification are (1) Single-phase—Alternating. (2) Split-phase—Alternating. (3) High Voltage—Direct Current.

The single phase commutating motor has been in operation upon interurban electric railways for some years, and a study of the history of these installations reveals some of the fundamental reasons why this type of motive power has not been more generally adopted. It has been found that the initial expense and cost of upkeep of rolling stock equipped with single-phase commutating motors is fully double that of cars having the same seating capacity and equipped with direct current motors. No new installations have been made for the past two years, and the several single-phase roads are being changed over to direct current as fast as financial conditions will permit.

The introduction of the single-phase system was a result of the success of suburban and interurban electric railway operation and the extension of these lines over large areas, thus bringing into prominence the question of economical power distribution. It was recognised that a voltage higher than the commonly accepted standard of 600 volts was desirable upon the trolley in order to minimise the cost of installing feeder copper and substations. While the single-phase motor was being developed and installed upon interurban railways, careful attention was also being given to the question of the possibility of using direct-current motor equipments at higher voltages and resulted in the installation of the first 1,200 volt road, the Indianapolis and Louisville Traction Railway, operated in 1907. The success attending this operation led to other similar installations at both 1,200 and 1,500 volts until it is now generally recognised that the high voltage direct-current system is without a competitor for all classes of suburban and interurban electric railways. It is a safe prediction to make that no more single-phase motor equipments will be placed in operation in this country on new roads unless these roads virtually form an extension of existing systems. All the direct-current equipments are operating with the highest degree of success and no change of type of equipment has been made or any such contemplated.

The history of the battle of the systems and the elimination of the single-phase motor as being unsuitable for the equipment of light electric railways has an important bearing upon the selection of systems for main line electrification. The limitations of the single-phase motor that lead to its failure in the interurban railway field do not appear to be lessened when considering it for locomotive equipment, with the result that it is in use but on three of the 12 roads that are truly representative of electrified steam roads operating large electric locomotives.

Main Line Electrification—United States and Canada.

Installation.	Year.	Type Locomotive.	System.	Voltage
St. Clair Tunnel ..	1908	Geared	Single-phase alternating	3,300
N.Y., N.H. & H. ..	1907	Gearless ..	Single-phase alternating	11,000
Hoosac Tunnel....	1911	Geared	Single phase alternating	11,000
Cascade Tunnel ..	1909	Geared	Three phase alternating	6,600
*Norfolk & W't'n	1914	Geared Side Rod.	Split phase alternating	16,500
Baltimore & Ohio Tunnel.	1895	Geared	Direct current	600
New York Central	1906	Gearless ..	Direct current	600
Detroit Tunnel ..	1910	Geared	Direct current	600
Pennsylvania Terminal	1910	Side Rod ..	Direct current	600
Butte, Anaconda & Pacific.	1913	Geared	Direct current	2,400
*Canadian N'thern	1914	Geared	Direct current	2,400
*Canadian Pacific	1914	Geared	Direct current	2,400

* Under construction.

There are other electrified steam lines, but the service on them more nearly approaches that of high class electric interurban railways. Also there are interurban systems where electric locomotives of considerable capacity are operated, but the class of service does not approach the exacting demands of

* Abstract of paper read before the Canadian Society of Civil Engineers, December 18th, 1913.

main line passenger and freight operation. The preceding table, however, comprises converted steam lines where the service consists of hauling main line passenger and freight trains behind electric locomotives of large capacity.

It is a noteworthy fact that the use of the single-phase motor has not extended beyond the two original roads installing this type of equipment, the Grand Trunk and New York, New Haven and Hartford (including Hoosac Tunnel installation), whereas direct-current motors have been universally adopted in all the more recent electrifications with the single exception of the proposed split-phase installation on the Norfolk and Western Railway. The so-called "split-phase" system is a comparatively newcomer in the electric traction field and it has not yet been subjected to the test of actual

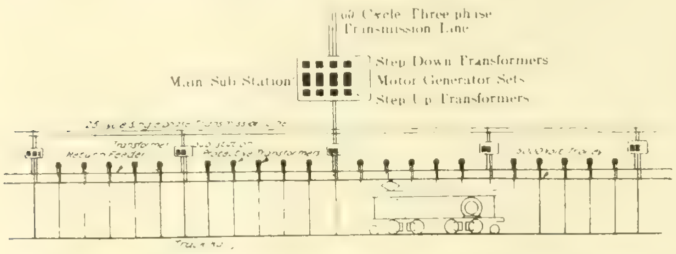


FIG. 1 GENERAL SCHEME OF SPLIT-PHASE ALTERNATING-CURRENT SYSTEM.

operation. The proposed system offers many attractive features, however, and it is worthy of careful study in order to understand its fitness for heavy electric railway service. From experimental tests made, it seems reasonably certain that the split-phase locomotive can meet the demands of commercial operation with satisfactory reliability.

Confronted with the problem of main line electrification and the demand for a distributing system which would provide for the economical distribution of large units of power over an extended area, the need of higher direct-current voltage was appreciated and resulted in the first installation of 2,400 volts direct current upon the Butte, Anaconda and Pacific Railway, first operated May 28th of this year. This installation marks an epoch in electric railway progress, as its success offers substantial proof that direct-current motor equipments can be constructed at a reasonable cost and operated in an efficient and reliable manner with trolley potentials as high as 2,400 volts. It has been characteristic of the installations operating at 1,200 and 1,500 volts that the reliability of the direct-current motive power has been in no way impaired by reason of using a higher trolley voltage, in fact, the maintenance of 1,200 volt motor equipments shows no increase over that of 600 volt equipments. A brush life of over 150,000 miles gives evidence of good commutator performance with practically no wear and the increased insulation and creepage distance provided has been ample to ensure reliability and low cost of maintenance. The transition from 1,2C0 to 2,400 volts direct current has also resulted in completely successful operation at this potential. The operating record of the Butte, Anaconda and Pacific 2,400 volt direct-current system has been truly remarkable.

The success of high voltage direct-current installations has not been marred by a single instance of failure due to fundamental defect in the type of apparatus used, and justifies the conclusion that the 2,400 volt, 1,200 volt, and the 600 volt direct-current equipments are all part of the same general direct-current system, and that the only difference is the need of more insulation in one case than in the other. The 2,400 volt direct-current installation of the Butte, Anaconda and Pacific cannot be looked upon, therefore, as in any way constituting a new "system" of electrification, but rather as a natural development along the lines of higher voltage of the same well-known direct-current system which has rendered such excellent account of itself in the past, on all our city, and practically all of our surburban and interurban electric lines. This has an important bearing upon the general electrification of the steam roads, as it places the status of the direct-current system as applied to such service.

Fully appreciating the grave responsibility of selecting a type of motive power for a proposed electrification that holds promise of special fitness for the immediate service contemplated and also is capable of meeting the demands of unlimited future extensions, this paper will briefly touch upon the comparative characteristics of the split-phase and 2,400 volt direct-current systems of operation. The choice seems to lie between split-phase and direct current inasmuch as the history of the single-phase motor equipment does not seem to justify its further consideration for heavy electric railroading.

A general scheme of distribution to the split-phase locomotive is shown in Fig. 1 which has special application to western railways where 60 cycle power supply is universally standardised. A corresponding diagram of the 2,400-volt direct-current system is shown in Fig. 2, this also being adapted to 60 cycle power supply. Starting first with a comparison of the two types of locomotive, it is necessary to make some general assumption as regards service conditions in order to draw conclusions as to relative locomotive characteristics. The electric locomotive is capable of being constructed in very large units, but convenience in shopping and simplicity in construction both point to a unit of approximately 100 tons total weight on drivers. These 100-ton units can be coupled together and operated as a single locomotive of any desired capacity, though probably a two-unit locomotive weighing 200 tons and giving a starting tractive effort of 120,000lbs. is as large as the draught gear will stand. Experience with steam locomotive practice seems to point to a locomotive rating on ruling grade that calls for a tractive effort corresponding to approximately 18 per cent. coefficient of adhesion on drivers. Thus the conditions obtaining upon a 2 per cent. ruling gradient will be as follows:—

Tractive effort due to 2 per cent. grade	40lbs.
,, ,, ,, train resistance	6lbs.
,, ,, ,, curve resistance	2lbs.
Total per ton	48lbs.

Total weight on drivers	200,000lbs.
Rating at 18 per cent. coefficient of adhesion	36,000lbs.
Gross train weight	750 tons
Trailing train weight	650 tons
Speed	15 m.p.h.
Net output at drivers	1,450 h.p.

A maximum load of 50,000lbs. per axle has been assumed as being within acceptance of good practice. The question of speed on ruling grade is one subject to local requirements, but in general a speed of 15 m.p.h. on 2 per cent. grade is as high as desirable on roads of moderate tonnage. As ruling grade generally extends unbroken over comparatively short distances, it is possible to take advantage of this fact in electric

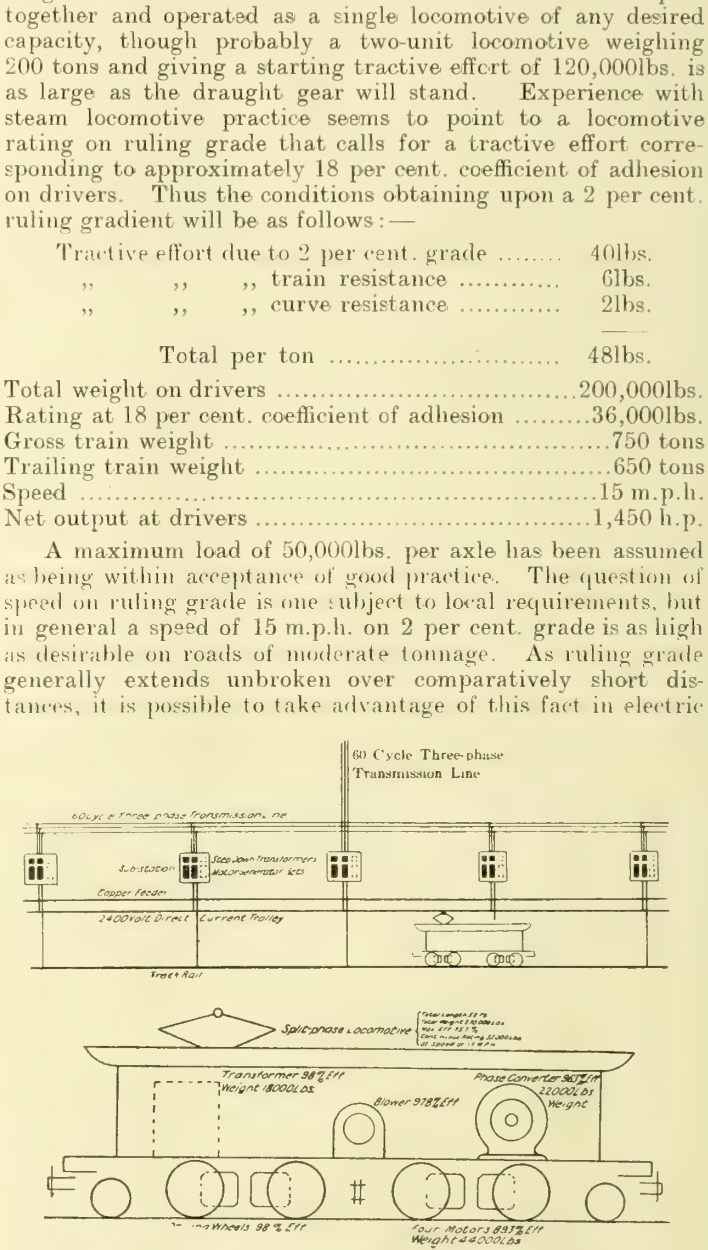


FIG. 2. GENERAL SCHEME OF 2,400 VOLT DIRECT-CURRENT SYSTEM.

locomotive design and proportion the motive power for a continuous capacity of, say, 16 per cent. coefficient of adhesion without danger of exceeding safe temperature limits in operation. The continuous capacity of the 100-ton unit would therefore be 32,000lbs. tractive effort at slightly more than 15 miles per hour, based upon 16 per cent. coefficient of adhesion of the weight upon the drivers. Owing to the moderate speeds at which a freight locomotive will operate, it is entirely feasible to consider a construction wherein the motors are geared direct to the driving axles by twin gearing.

in this respect following the practice of the Detroit Tunnel, Cascade and B. A. P. locomotive, which has proved very successful. For the purpose of this comparison, it is assumed that both split-phase and direct-current locomotives will be of similar construction and employ twin geared motors of equal weight and efficiency. A comparison of weight distribution in the two types of locomotives is presented herewith.

Comparative Weight of Locomotive—Continuous Capacity 32,000lbs.—15 M.P.H.

	Split-phase.	2,400 Volts Direct Current.
	Lbs.	Lbs.
Four motors	44,000	44,000
Control apparatus complete	17,000	27,000
Air compressor	4,000	4,000
Air brake equipment	3,000	3,000
Miscellaneous	2,000	2,000
Phase converter	22,000	-
Transformer	18,000	
Cab and running gear	160,000	120,000
Total	270,000	200,000

As the direct-current locomotive of 100 tons carries no ballast, it is evident that the 40,000lbs. comprising the phase converter and transformer of the split-phase locomotive must be carried on idle wheels, together with the additional weight of cab and running gear required to carry this excess weight. The net result is a split-phase locomotive of fully 35 per cent. more weight than a direct-current locomotive of equal capacity and of similar construction. This weight comparison is based upon the assumption that 50,000lbs. per axle constitute the limit allowable, thus forcing the introduction of guiding axles to carry the excess weight of the split-phase equipment. For locomotive construction of less capacity permitting the split-phase to come within axle weight limits, both types of locomotives would comprise four axles with no guiding wheels, and the split-phase locomotive may not total more than 20 per cent more than the direct-current type. It is evident that the split-phase locomotive is not only considerably heavier for equal capacity, but also more complicated and inefficient than the direct-current locomotive. The power from the trolley must in turn pass through transformer, phase converter, control, motors and gears. The efficiency of the complete locomotive in operation will depend upon its output, and hence in the following comparison efficiency has been computed for operation on both ruling grade and level track. The average efficiency of a day's run will obviously lie somewhere between these values, assuming that portion of the run when the locomotive is taking power.

Freight Locomotive Efficiency—Detailed Comparison.

	Split-phase.		2,400 Volts Direct Current.	
	Ruling Grade.	Level.	Ruling Grade.	Level.
	Per cent.	Per cent.	Per cent.	Per cent.
Motors and gears	89·3	86·0	89·3	86·0
Blower	97·8	95·8	97·9	95·9
Starting resistances	98·6	98·0	99·2	99·4
Phase converter	96·3	94·7	–	-
Transformer	98·0	97·0	-	-
Wheel correction	98·0	98·0	-	—
Weight efficiency	95·0	97·0	–	–
Combined efficiency	75·7	70·5	86·6	82·0
Average of grade and level	73·1 per cent		84·3 per cent.	

(To be continued.)

Institution of Municipal and County Engineers.—The date for the annual conference of the Institution of Municipal and County Engineers, which is to held in Cheltenham, has been fixed definitely for June 24th, 25th, 26th, and 27th next. It has been decided to make a special feature of town planning and also of roads, and, if possible, to arrange for an exhibition of town plans.

VANADIUM IN BRASS.

The properties of special brasses were discussed in a paper on "Vanadium in Brass," by Messrs. R. J. Dunn and O. F. Hudson, read at a recent meeting of the Birmingham Section of the Institute of Metals. Small quantities of other metals, said Mr. Hudson, who read the paper, were often intentionally added to copper-zinc alloys in order to produce brasses which had special qualities, and had been called "special brasses." The metals most commonly used were tin, lead, iron, manganese, and aluminium, giving naval brass, delta metal, manganese bronze, and many other well-known alloys. Vanadium was also used to some extent, and was added in the form of cupro-vanadium, the resulting brass being known generally as "vanadium bronze." The majority of special brasses contained about 55 to 60 per cent. of copper, and sometimes less, the one or more added metals replacing part of the zinc. Their mechanical properties were superior to those of the corresponding ordinary brasses, at least as regarded tensile strength. The elastic limit also was usually raised and the alloys were harder. At the same time the ductility was not much affected or was sufficient for the purpose to which the brass was to be put. In addition many special brasses were of particular value owing to their power of resisting corrosion. Published results (although few in number) of tests of vanadium brasses indicated that the use of cupro-vanadium gave considerable increase of strength, and it was also stated that it much reduced the tendency to corrosion. The work which the authors had carried out was designed to ascertain if small percentages of vanadium had any effect on the constitution and structure of copper-zinc alloys, and the conclusion was that on the whole annealing appeared to have rather less effect on vanadium brasses than on pure brasses. It was probable that the beneficial effect of vanadium was largely due to its deoxidising power, but in that and in other respects it was difficult to estimate the exact effect of vanadium owing to the comparatively large amounts of aluminium and other metals present in many samples of commercial cupro-vanadium.

OFFICIAL TESTS WITH FIRE EXTINGUISHERS.

The British Fire Prevention Committee devoted considerable time last year to an exhaustive investigation into the reliability of existing portable chemical fire extinguishers, in which enquiry they had the co-operation of a number of Government departments, corporations, and institutions, who lent the committee extinguishers which had been in their possession for periods varying from a few months to as long as 35 years. The reports on these investigations have been issued by the British Fire Prevention Committee as Red Books Nos. 185 and 186, of which the latter may be deemed the more important, and contains a comparative table as to the results of tests with about 100 appliances in all. It is interesting to observe that the great majority of the appliances under test were of British make, and that all existent types of extinguishers (although not every individual make) were under investigation. Regarding the strength of the appliances and their aptitude to burst which has caused fatalities, it is interesting to observe that out of a series of 57 extinguishers tested hydraulically, 10 failed at under [illegible]00lbs. pressure, and 8 failed to withstand the committee's official 350lbs. pressure test, whilst 33 passed the last-named test. Several already burst at 200lbs. The working pressure generated by one of the extinguishers when the nozzle was closed, was 310lbs., and in another case it was 340lbs., which plainly shows the wisdom of the committee insisting on a margin of safety for the future. The Fire Prevention Committee's reports deal with many aspects of the extinguisher question, and Memorandum III. (signed on behalf of the Extinguisher Research Sub-committee, Mr. D. W. Wood) is a particularly valuable contribution. The principal series of tests were conducted by a sub-committee comprising two district surveyors, seven fire brigade officers, two insurance surveyors, two insurance experts, and a chemist, under the supervision of the executive and representatives of the committee's council.

BOOK REVIEWS.

Fowler's Mechanical Engineer's Pocket-book, 1914. By William H. Fowler, M.Inst.C.E., M.I.Mech.E., &c. Scientific Publishing Company, Manchester. 6in. by 3¾in.; 576 pp. Price 1s. 6d. net, cloth, or superior binding, gilt edges, 2s. 6d. net.

In this, the 16th annual edition of this cheap and compendious reference book of mechanical engineering, the author has, we notice, taken advantage of its annual publication to bring it up to date in respect to various developments in power practice. The Board of Trade rules on boiler construction have been overhauled and the latest modifications embodied. We notice also that the Bone system of surface combustion and Nicolson's experiments on gaseous high speed and their effect on heat transmission are fully explained and reduced to figures, while some useful data are compiled from various sources on the subject of heat transmission through boiler plates. The sections relating to steam turbines and large gas engines have been similarly revised, while that on pumps gives some interesting data and includes a description and figures of tests of the latest development in this direction, viz., Humphrey's gas pump. These do not embrace all the emendations, but they serve to show the up-to-dateness of this now well-established publication. Finally, a word of praise should be paid to the excellence of the innumerable tables of data with which the book is furnished, and especially the steam table, which has been compiled by W. W. F. Pullen, and gives the properties of steam up to pressures of 250lbs. on the inch. The book is extraordinary value for the money, even in these days of cheap technical text-books.

* * *

Fowler's Mechanics and Machinists' Pocket-book and Diary, 1914. Manchester: Scientific Publishing Company. 6in. by 3¾in.; 450 pp. Price 6d.

450 pages of carefully selected technical information bearing on the design, construction, and working of all kinds of machine tools, collated and digested so as to permit of quick reference—and all for sixpence—is, we think, about the high-water mark of cheapness in technical literature. It is certainly marvellous money value, and is, of course, only possible on the basis of the enormous circulation which the book has acquired, not only in the United Kingdom but in the British Colonies and the United States. No other book can compare with it for range or usefulness of information, even at many times the price. The book is absolutely free from padding or puffing, and this feature has doubtless contributed largely to the esteem in which it is held by machine workers, foremen, and draughtsmen all over the world.

* * *

The Mechanical Engineer's Reference Books. By H. H. Suplee. Lippincott Company, Philadelphia; Chas. Griffin & Co., London. 6½in. by 4¼in.; 964 pp. Fourth edition.

This book contains a wide assortment of information in the way of mathematical tables, weights of materials, proportions of parts, and data relating to boilers, engines, pumps, and electrical machinery, but it is an American production, and much of the information necessarily pertains to American practice. At the same time there is much which the British draughtsman or engineer will find useful. The book is clearly printed, though the type is small and the paper thin, while the tables are also very clearly arranged. No indication, however, is given as to the price. This defect is common with many publications, though we fail to see what advantage can accrue to either authors or publishers from the suppression of this fact, or why it should not be clearly set forth on the title page.

* * *

Molesworth's Pocket-book of Engineering Formulæ. 27th edition. By Sir Guilford, L., and Henry Bridges Molesworth, with an Electrical Supplement by Walter H. Molesworth. London: E. & F. N. Spon. 936 pp. Price 5s. net.

This friend of our early days still preserves the affectionate regard of a large section of engineers—more especially those who are engaged in what is conventionally termed civil in contradistinction to mechanical engineering. Though the requirements of the latter in the shape of pocket-books of reference have been more amply and specially met during recent years owing to its rapid growth and specialisation, there is no hard and fast line of demarcation between the two branches, and the book under notice contains much matter that is of service to the one as well as the other, while in addition a special supplement of some 100 pages is devoted entirely to electrical data. Although three joint authors are engaged in this production, they all possess the family name of the founder, which has become a household word amongst engineers. It is, of course, impossible to summarise the contents of a reference book such as this; we content ourselves therefore with saying that it is brought up to date and fully maintains its traditional reputation.

* * *

Dictionary of German-English and English-German. By Max Bellow. London: Longmans, Green, & Co. 806 pp. Price 6s. net.

A dictionary does not usually offer much for the reviewer to notice in the columns of a technical journal, but the one under notice has some exceptional features which differentiate it from the common run, as far as engineers are concerned, since special attention has been paid to the many new technical words which have crept into all European languages of recent years, as a result of scientific discoveries and the evolution of new branches in mechanical and electrical engineering. The lexicographer may be excused if he ordinarily passes over many of these, for they do not come under his ken unless he specially looks for them, and their equivalent is equally difficult to find in a foreign tongue without expert assistance. In this respect the author has been fortunate, and without pretending to be a dictionary of technical terms it will be found to contain most of those the general reader is likely to come across or require in his average reading or correspondence. A word of praise is deserved for the excellence of the type and the clearness of the printing—small details, perhaps, but very important in a work of this kind.

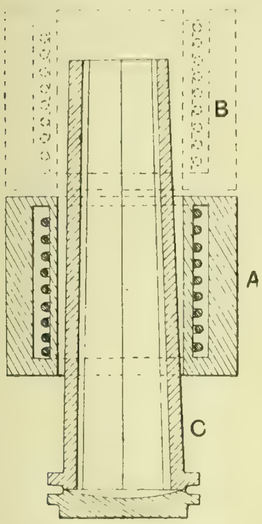
PREVENTING PIPING IN STEEL INGOTS AND CASTINGS.

NUMEROUS processes have been proposed for the purpose of preventing piping in steel ingots and in metal castings generally. In the case of steel ingots particularly, piping results in considerable loss, for a relatively large portion of the ingot in which the piping occurs is of no value for rolling or subsequent mechanical treatment, and has to be re-melted. Piping is largely due to the unequal contraction of the mass of metal in cooling, which, together with unequal cooling, results in the centre of the ingot shrinking. To prevent piping it has been proposed to cast the metal under pressure, or to cast in moulds in which the cross-section of the ingot is reduced by forcing the metal during cooling through an aperture of progressively contracting cross-section. Other methods for preventing piping are based upon the principle of regulating the cooling so as to ensure equal contraction of the mass of metal; the higher portion of the ingot or the gate of the casting being retained at a higher temperature than the lower portions, or retained in a fluid condition during the solidification of the lower portions, so that the fused metal follows downward the solidifying metal. For this purpose it has been proposed to employ as heating means gases or mineral oils or a cap of solid fuel which is burned under the influence of a jet of air or a cap of an alumino thermic material.

Another process has recently been patented by Messrs. Gio. Ansaldo & Co., No. 2, Corso Andrea Podestà, Genoa, Italy, in which the ingot or casting is heated by electric currents induced in the metal by means of an alternating current in a metal coil surrounding the metal to be treated. The heating apparatus for carrying out the process comprises essentially a hollow annular casing adapted to surround a greater or smaller part (according to the size of the ingot to be produced) of the ingot mould and a coil or coils of conductor. This casing is capable of being shifted axially in relation to the mould or is arranged so that the heating zone may be raised in a vertical direction. The accompanying

illustration shows the apparatus applied to an ingot mould. An alternating electric current flows in the coiled metal wire which is protected by a hollow cylindrical casing A of refractory material. Induced currents are set up in the mass of steel constituting the ingot or casting by the alternating current, the characteristic features of the induced current depending upon the periodicity of the alternating current in the coil.

The process is carried into effect as follows: Referring to the illustration, when all the steel required to constitute the ingot has been poured into the mould, the heating casing A surrounding the mould occupies its lowest position, for instance, the position A shown in full line on the illustration. As soon as the heating commences the annular heating apparatus is raised gradually until it occupies the position B indicated in dotted lines, where it encircles the highest portion of the ingot mould. The intensity of the heating and the most convenient means for shifting the heating zone in relation to the mould depends greatly on the shape, dimensions, and material of the mould, the temperature of the steel at the time of pouring, the composition of the steel, and must be determined by trial in each case. In cases where the heating is not too intense ordinary ingot moulds of metal, such as cast iron, may be employed. Even in such cases, however, it is advisable to provide the ingot mould with a lining of refractory material. When the heating is intense the ingot mould must be made wholly or in part of refractory material. The process is equally applicable to all kinds of steel castings in moulds having shapes very different from the usual ingot shape, and excellent results have, it is stated, been obtained in such cases. Instead of shifting the heating apparatus gradually from the bottom to the top of the ingot mould, the apparatus may be constructed of such length as to envelop the entire length of the ingot mould, and be operated in successive sections, each section corresponding in length to the portion of the ingot mould which is to be heated at the time.



Apparatus for Preventing Piping in Steel Ingots.

The Junior Institution of Engineers: North-western Section.—The members of the North-western Section of the Junior Institution of Engineers paid a visit to the Broadheath works of the Linotype and Machinery, Ltd., on Saturday afternoon, the 17th ult. They were conducted over the works by members of the staff, and were shown many of the latest and best things in the printing-machine trade. One of the most remarkable features seen was the extreme accuracy observed in manufacture and the up-to-date testing appliances installed in the works to test and ensure this high standard of accuracy. At the close of the visit a hearty vote of thanks to the Linotype and Machinery, Ltd., for the privilege afforded the Institution was moved by Mr. Hatch and seconded by Mr. Hird and cordially carried. Mr. C. H. Prichard responded on behalf of the company. A meeting of the section was held in Manchester on Friday evening, the 23rd ult. A discussion on "The Metric versus British Systems" was opened by Mr. C. H. Prichard, who spoke in favour of the adoption of the metric system. In the discussion which followed objections were raised to any change being made because of the practical difficulties in the way, such as existing gauges, measuring tools, &c. On the other hand, commercial advantages in using the metric system when trading with countries using that system were well illustrated. The presidential address on "The Future of Oil Fuel," by Sir Boverton Redwood, Bart., D.Sc., F.R.S.E., M.Inst.M.E., F.I.C., &c., President of the Junior Institution of Engineers, was read by Mr. N. Gerard Smith before a meeting of this section of the Institution, held in Manchester on Thursday, January 29th.

EXPLOSION OF AN OIL SEPARATOR.

On January 28th and 29th a "formal" Board of Trade enquiry was held at the Stevenson Memorial Hall, Chesterfield, the Commissioners being Mr. A. B. Bence-Jones, barrister, and Mr. A. T. Maginnis, M.Inst.C.E., to enquire into the circumstances attending the explosion of an oil separator which occurred at the Devonshire Works of the Staveley Iron Company on April 2nd of last year, killing one man and injuring three others.

It appears that on the day of the accident it became necessary to change the direction of flow of exhaust steam from one of the engines at the works, which was then discharging through an oil separator into a water tank, so as to divert the exhaust into the steam main leading to a turbine, and the works engineer, to make the change, took several men with him to the top of the separator in case the change-over valve, which was of the sluice type, should prove stiff to move. In addition to this valve there was also a wing valve fitted with a balance lever, which was operated automatically and swung over to cut off the opening to the water tank, and the deceased was inadvertently standing in such a position that when the lever swung over as it was intended to do it jammed his legs against the chest of the sluice valve. It was impossible to release him without stopping the engines, and the engineer turned away to give instructions for this to be done. At the same moment one of the other men closed the sluice valve again, thinking this would relieve the pressure on the man who was held fast, as he was being crushed. The effect, however, was to cause an excess of pressure in the oil separator, which was about 7ft. diam., and it almost immediately afterwards burst, with the results stated.

Evidence was given to show that the explosion was due to the accumulation of back pressure in the exhaust from the engine, owing to the closing of the two exhaust passages, and that the separator was amply strong for the work it was normally designed to perform.

In delivering judgment, Mr. Bence-Jones said Mr. Maginnis and himself were of opinion that the enquiry showed the imperative necessity of fitting a safety valve not liable to be shut off on all steam receptacles, pipe ranges, &c., whether exhaust or otherwise, when there was even a remote chance (as in this case) that all outlets might be closed. He then dealt seriatim with the questions put to them by Mr. Vaux on behalf of the Board of Trade.

Question 1: When and by whom was the separator which exploded made, and when was it fitted up at the Devonshire Works? At what pressure was it worked thereafter?

Answer: It was made in the year 1906 by the Baker Oil Separator Company, Ltd., now of Hunslet, Leeds. It was fitted at the Devonshire Works some months later by the Staveley Coal and Iron Company, Ltd. Thereafter it was worked at exhaust pressure up to 9lbs.

Question 2: Was the separator fitted with adequate mountings, and was the arrangement such as to ensure safety in working?

Answer: Yes, under normal working circumstances.

Question 3: Were proper measures taken by the Staveley Coal and Iron Company, Mr. Charles P. Markham, the chairman of directors, and Mr. Ronald Fowler, engineer of the Devonshire Works, to ensure that the separator was worked under safe conditions?

Answer: Yes.

Question 4: What was the cause of the explosion?

Answer: Efforts to release a workman who was fatally jambed by the lever of the change-over valve, which efforts consisted in hurriedly closing an outlet valve on the exhaust system, and so allowing undue pressure to be put upon the shell of the separator.

In regard to the question whether the Staveley Coal and Iron Company, or any of its servants, were to blame for the explosion, he said their answer was "No," as the explosion was brought about by an accident to one of the workmen, and, under these circumstances, the Court made no order as to the costs of the investigation.

THE MEASUREMENT OF STRESSES IN MATERIALS AND STRUCTURES.*

BY PROF. E. G. COKER, M.A., D.SC.

(*Continued from page* 110.)

THE stresses produced in beams subjected to given uniform bending moments have been examined by measuring the thermal changes produced at various points in the cross-section, and in the example shown by Fig. 21 a steel bar, I-beam, was examined at five different places by means of a thermopile pressed against the metal of the flanges and the web. The deflections of a galvanometer in circuit with the

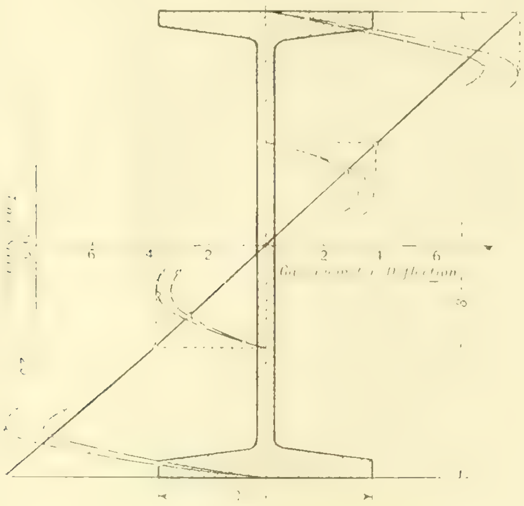


FIG. 21

thermopile were obtained for approximately equal loadings applied at a uniform rate, and the corrections for radiation and conductions were determined by observation of the change in reading when the load was maintained at its highest value. The observed and corrected readings for this case are plotted in the accompanying diagram (Fig. 21) as curves starting from the points of observation, and the maximum values are used to infer the stress distribution across the section. The experimental values show that there is a linear distribution of the stress across the section, a result which was confirmed by independent strain measurements.

In another test of a bent beam the measurements of strain and thermal change were not in good agreement, and it is therefore important to determine the reason for the discrepancy. The beam subjected to test was a channel section carried on supports 60in. apart, the load being applied in equal halves at points 9in. distant from the centre of the beam. Strain measurements with a roller extensometer showed a normal linear distribution across the section of the beam, corresponding to those described in Fig. 4; and apparently we have here what appears to be an ordinary case of bending, since the distribution is similar to the previous case. A number of thermal measurements were made at different points of the cross-section, which showed, however, that this was not the case. It is not necessary to give here all the detailed observations which were recorded, as the experimental observations are necessarily very numerous and the corrections laborious. All the experimental curves yielded results of a similar type, and since the testing machine was so constructed that the loading could not always be stopped exactly at the required maximum, a small proportional correction is required in a few cases to reduce the readings to a common basis. When this is done readings are obtained proportional to the applied bending moment, as indicated in Table IX. And these values are plotted in the correct relation to the section on Fig. 22A. The thermal indications are here no longer proportional to the distance from the centre of the depth of the beam, as are the strain measurements, and we infer that the distortion of the web produces stresses and strains in a direction at right angles to the length of the beam owing to the want of symmetry of the section, and a thermal effect is produced proportional to the sum of the principal stresses at the place of observation. The strain-measuring instrument is, however, unable to measure both principal strains, and it fails, in fact, to reveal the serious change in the stress distribution arising from the want of symmetry of the beam.

TABLE IX.

Bending Moment. Inch-lbs.	Position of Thermopile.				
	Top Flange of Beam.	1⅝in. above Centre of Depth.	Centre of Depth.	1⅜in. below Centre of Depth.	Bottom Flange of Beam.
13,000	18·62	5·22	2·03	2·50	·10·51
26,000	13·05	3·41	1·42	−4·50	7·70
39,000	6·17	1·64	0·72	−6·70	3·71

Stress distribution may also change owing to the bending of members subjected to pure compression, and an example of this is afforded by pillars. Thermal measurement is capable of detecting stress distribution of this kind, as shown by the following experiment upon a steel compresssion member, 15in. long and 1⅜in. by ⅝in. in cross-section, subjected to a load of 4,000lbs. The thermopile used in this case was a linear one pressed against the broad face of the specimen at various points of the length. The maximum deflections differed very little from one another, and there was no perceptible lag of the galvanometer, so that the corrections to be applied affect all the measurements nearly equally. The actual readings therefore give the comparative distribution of stress in the member, and are plotted as ordinates in their proper positions with reference to the points of observation. The measurements show (Fig. 22B) that there is a decided increase on stress intensity in this short pillar as we approach the centre, and they demonstrate the possibilities of thermal measurement for this type of experimental investigation. It is also worthy of mention that thermal effects proportional to the stress have been obtained in cement blocks of considerable age,† and in bodies like stone and slate, but no such effects were obtained with specimens of cement and concrete when subjected to compression or bending stress, a few months after moulding.

Effects due to the differences of thermo-electric condition of stressed and unstressed metal have also been observed by Magnus and Thomson, while the later researches of Ewing have shown that within the elastic limit the thermo-electric values obtained are not proportional to the stress, and are also affected by previous stress actions. The thermo-electric quality in relation to a cycle of stress is, in general, represented by a closed or nearly closed curve, and the same stress may therefore correspond to widely different thermo-electric

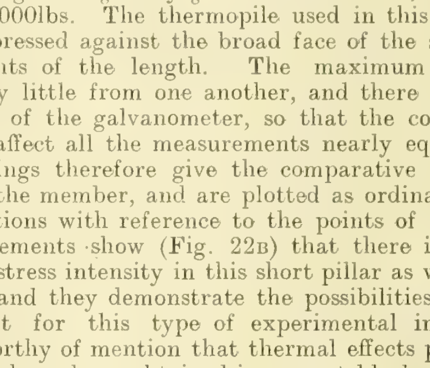


FIG. 22A.

values, which, however, tend to reach approximate equality if the metal is mechanically vibrated during the application and removal of load. An example (Fig. 23), taken from my laboratory notebook, indicates the general nature of the thermo-electric effect at the junction between stressed and unstressed iron wire when treated by steam at atmospheric pressure. A cycle of stress within the elastic limit of the material produces thermo-electric changes (curve 1) which differ for loading and unloading, and in the succeeding stress cycles the effects of the previous loadings appear greatly to influence the thermo-electric state, so that we have no very

* Cantor lectures delivered before the Royal Society of Arts, December, 1913, and reproduced from the Journal of the Society.

† "The Relation of Thermal Change to Tension and Compression Stress." By E. G. Coker and C. M. McKergow. "Transactions," Royal Society. Canada, 1904.

certain means of determining stress distribution in materials by observing its thermo-electric condition.

In considering other possible ways of determining the distribution of stress in materials, it has already been seen how important it is to measure the stress at a point, and the preceding discussion has shown some of the advantages, and also the difficulties which are met with, when strains or thermal effects of stress are used for this purpose. If, however, a body is elastic we may make use of any of the properties it possesses which will allow us to infer the stress distribution, and in this respect it is of importance to note that many transparent bodies when loaded acquire the temporary property of doubly refracting the light passing through them. This property, discovered by Brewster, is of great interest and importance, as it furnishes, although somewhat indirectly, a measure of the stress at a point. Double refraction is not usually observed in transparent bodies under stress owing to the ordinary conditions not being favourable for observation, but if the light passing through a stressed object is such that its transverse vibrations are of particular types, the effects of stress may be readily made visible to the eye. A beam of light, in which all the transverse vibrations are executed in one plane, affords a ready means of detecting double refraction, and a simple means of obtaining light of this kind is to cause a beam of ordinary light to impinge upon a black glass surface at a particular angle; the reflected beam is then found to be of the type required, or plane-polarised, as it is usually termed. If such a beam is transmitted through a stressed transparent plate it is broken up into two distinct beams executing vibrations in planes at right angles to each other, and to the line of direction of the pencil. This selective effect is, moreover, accompanied by a retardation of the velocity of propagation of both waves during their passage through the stressed medium, but of different degree, so that when they emerge there is a phase difference of vibration, which persists in their subsequent passage through the air. Waves of light of this kind do not interfere with each other so long as the vibrations are in perpendicular planes, but if the vibrations take place in the same plane an interference effect is produced, which may be very imperfectly likened to that produced by two systems of water waves travelling in the same direction with different velocities. The combined effect of the two systems may, at some places, give a wave of greater amplitude, while at others, where the crests and hollows coincide, there may be little or no motion. Components with reference to any given plane of waves of light vibrating at right angles may be readily obtained by using optical devices like Nicol's prisms, black glass, reflectors, and the like, and if the light used is homogeneous in character we observe the effects of interference by the increased intensity of light at some places on the stressed specimen, and lessened intensity at others, or if white light is used in which the vibrations are more complex we obtain remarkable colour effects.

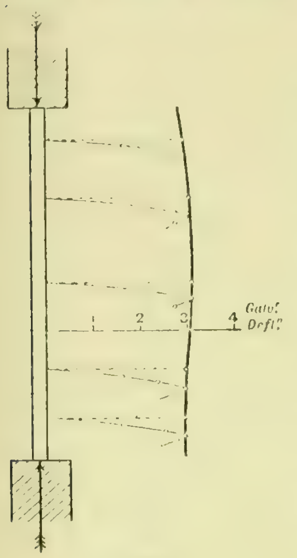


FIG. 22B.

We have already seen that the distribution of stress in a plate may be regarded as determined if we know at every point the directions of the principal stresses and their magnitudes, and it will be convenient to consider, first, how these directions can be obtained from a consideration of the manner in which a beam of plane-polarised light is divided by the action of the stressed medium. Experiment shows that the two component waves which leave a stressed plate of transparent material vibrate in the directions of maximum and minimum stress, and if the polarising and analysing devices are always arranged with their principal planes at right angles we have an arrangement which shows a dark point on the stressed object, wherever the directions of principal stress correspond to these principal planes. Usually these places appear as an assemblage of points, and reveal themselves as dark bands or areas, which change their positions as the optical apparatus is rotated, and in this way the positions of the axes of stress are defined for every point of the stressed object.

If we take the centre line of any band we can at once mark upon it the angular positions of the principal axes of stress, since they correspond to the observed angular positions of the principal planes of the polarising and analysing apparatus, and by extending these observations to all parts of the stressed object the directions of the axes of stress at every point can be determined with considerable accuracy. If, for example, we take a circular ring of transparent material cut across to form a hook, and stress it by means of two levers which force the cut ends apart, we notice that a black band appears when the object is viewed between crossed Nicol's prisms or their equivalents. This band marks the places where the principal axes of stress correspond to those of the optical apparatus, and it moves when these latter are turned through an angle. The various positions which such bands can take up afford a ready means of determining the angular positions of the axes of stress, and in general a sufficient number can be obtained to cover the specimen completely. Fig. 24, for example, shows the centre lines of a number of these bands for the cut ring obtained experimentally in this way, and in addition the angular positions of the axes of stress are also marked, and they form a map of the variations of angular position of the stress lines.

It is often convenient, however, to prepare a new diagram showing the way in which the directions of these axes change as we pass from point to point, and it will be readily seen from Fig. 24 that if we draw a line from any point traversing the stressed area in the directions of one set of axes of principal stress, we shall trace out a curve which is everywhere perpendicular to a second set of axes. We can, in fact, cover the area by two sets of orthogonal curves, which show us the directions of stress at every point as before, and we then have a new kind of map, such as is shown by Fig. 25 for the case of the hook, which, although it gives no further definite information, yet is more valuable, because it forms a kind of framework diagram showing the directions of the pulls and pushes in the material, while the spacing between the lines gives some notion of the stress intensity at a point. The distribution of stress at any section of this hook can be

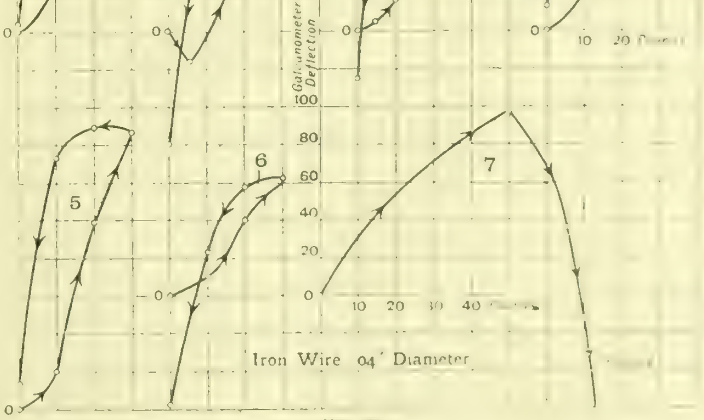


FIG. 23.

determined, and at the horizontal section it can be readily obtained with considerable accuracy by comparing the optical effects produced with those in a single tension or compression member, set along the lines of principal stress. For this purpose it is usually convenient to project a magnified image of both model and calibrating member upon a screen, so that minute differences in colour are more readily observable.

The breadth of the projected section in this example is adjusted to 2in., and the stress intensities at various points of the section are found by reducing the colour effect to a dark field at any required point by means of a stressed calibrating member. Some of the observations are shown in the accompanying Table X., and are plotted in Fig. 26, from which we observe that the maximum tension stress is reached

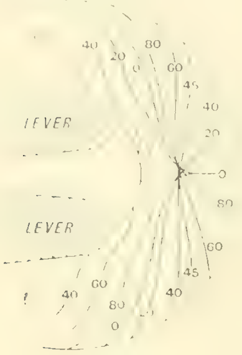


FIG. 24.

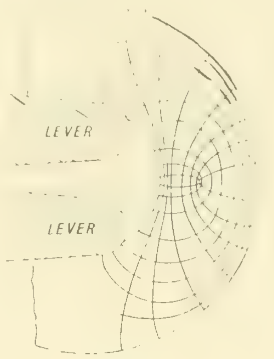


FIG. 25.

at the inner edge of the ring, and gradually decreases to a zero value at a point which agrees fairly well with the calculations of Andrews and Pearson for the neutral axis of

TABLE X.

	Abscissæ, inches.					
	0	0·16 to 0·25	0·5	Neutral Axis.	1·5	2·0
Stresses in pounds per square inch.	2,380	1,970 at 0·1	..	0·7	..	640
	3,370	2,380 at 0·16	..	0·7	950	1,270
	4,060	2,480 at 0·25	..	0·7	1,460	1,720
	4,570	..	1,460	0·75	1,910	2,730

a hook. It then changes to a compression stress, which finally reaches a low maximum value at the curved outer edge of the hook.

Another type of problem of importance relates to the effects of sudden changes of section in a member under load, a case of frequent occurrence in many kinds of practical engineering construction, as, for example, in members connected by riveted joints. An example of the simplest kind

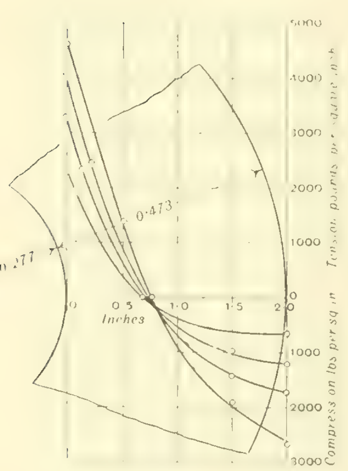


FIG. 26.

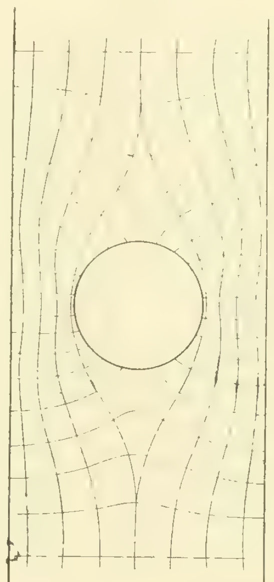


FIG. 27.

is furnished by the case of a single rivet-hole in a tension or compression member, such as occurs at the intersections of the members of the lattice webs of light girders. The lines of principal stress in the full section of a tension member when far removed from the hole may be conveniently represented by equally spaced lines, but this condition is clearly altered as they approach the hole, since the stress is not transmitted across it, but must be carried by the metal on each side. It is easy to determine the approximate positions of the lines of stress by the methods already described, and Fig. 27 shows one such experimental determination, from which it appears that not only do the lines approach one another at the minimum section, but they are also spaced unequally, and are closer together at the boundary of the hole, where a high stress intensity is indicated. The slight inclinations of the stress lines to each other also appear to show that transverse stress is present of small magnitude.

The distribution of stress in the neighbourhood of a hole in a tension member can be measured experimentally by optical means, and if the hole is of small diameter compared with the section of the bar the stress intensity at any point may be calculated. Thus at the minimum transverse section it can be shown that if p is the stress at a distance from the hole, the stress intensity p_x at any distance r from the centre of the rivet is given by—

$$p_x = \frac{p}{2}\left(2 + \frac{a^2}{r^2} + \frac{3a^4}{r^4}\right)$$

where a is the radius of the hole. This stress is accompanied by another p_y, at right angles and having a value—

$$p_y = \frac{3}{2}\left(\frac{a^2}{r^2} - \frac{a^4}{r^4}\right).$$

At the hole therefore the stress p rises to a maximum value of $3p$, while p_y is zero, so that we get a trebled stress

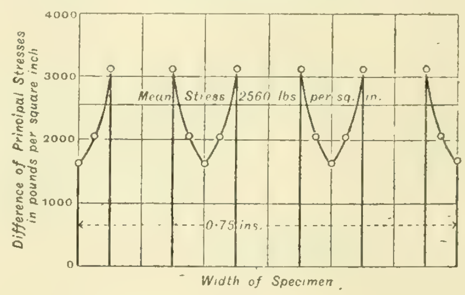


FIG. 28.

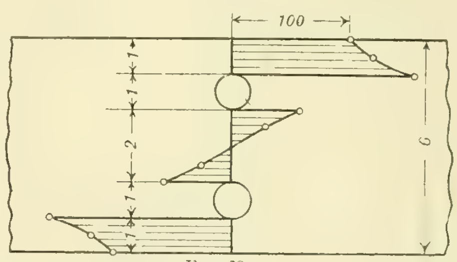


FIG. 29.

intensity just at the boundary. In practical cases, where rivet-holes are of appreciable size compared with the dimensions of the cross-section, we may compare the actual results obtained with a value of p calculated to correspond with a very broad section. Some experimental values* obtained from a model tension member are given in the accompanying Table XI., and they show that the maximum stress intensities are approximately $3p$, and also that the ratio of maximum stress to mean average stress steadily decreases as the hole is increased in size, as may be expected from general considerations.

TABLE XI.

Tension Member, 1in. by 0·186in. Load, 100lbs.

Diameter of central hole.	p.	Average stress intensity across section.	Maximum stress at rivet hole.
$\frac{1}{16}$	549	584	1,470
$\frac{1}{8}$	547	620	1,560
$\frac{1}{4}$	568	724	1,770
$\frac{3}{8}$	570	868	1,850
$\frac{1}{2}$	613	1,035	2,040

We can readily deduce by a simple application of the formulæ quoted above that the maximum stress is to the mean average stress in the ratio of $3c$ to $c+1$ approximately, where c is the ratio of the width of the plate to the diameter of the hole, and the experimental results of Table XI. agree fairly well with this simple rule.

* "The Effects of Holes and Semi-circular Notches on the Distribution of Stress in Tension Members," by E. G. Coker, Proceedings, Phys. Soc., Vol. XXV., 1913.

It seems certain that the yield point of a material is often exceeded at a rivet-hole, and in ductile material this is probably accompanied by an equalisation of stress in the neighbourhood of the hole. We can show that this latter effect takes place in ductile transparent material, and it seems not unreasonable to suppose that the mild steel plates used in riveted structures behave in a similar manner. If a more complicated case occurs with two or more rivets in a transverse section, the experimental determination of the stress distribution may still be made with little difficulty, and one such case is shown in the accompanying Fig. 28, where three rivet-holes diminish the section by one-half. In a test with a mean average load of 2,560lbs. per square inch the stress intensity was found to range from 1,600lbs. to 3,100lbs. per square inch, a much less range than occurs with a single hole giving the same diminution of area. The effect of bending also produces a very complicated distribution of stress at rivet-holes, and one such case is shown by Fig. 29, in which we have the singular result, owing to the effect of rivet-holes, that the greatest stress is at a point of the interior of the beam and not at the exterior surface.

So far we have not obtained a general method for determining the magnitudes of the principal stresses, and we must now enquire as to the methods by which their numerical values may be determined experimentally. For this purpose

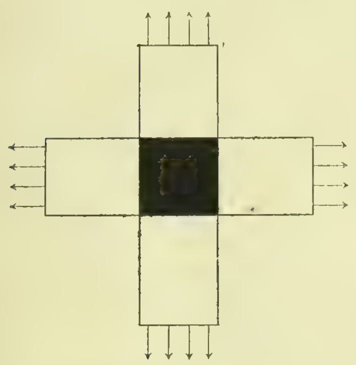


FIG. 30.

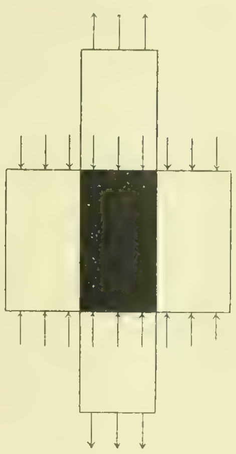


FIG. 31.

we can utilise the interference effects produced by the phase difference between the two rays into which the polarised beam is divided, and it is convenient for measurements of stress intensity to remove the effect by which we determine the positions of the stress axes. This is very easily accomplished by interposing a plate of a transparent material, which has the property of dividing a plane-polarised beam into two component waves vibrating at right angles, and of such a thickness that the phase difference on emergence is one-quarter of a wave-length of the light used. Mica is a convenient substance for this purpose, and if suitable plates are interposed on each side of the object under examination the beam of light between them becomes circularly polarised, and the black bands marking the directions of the stress axes are removed. The remaining effect is a measure of the stress in the material, and it is easy to show by simple experiments what are the relations between the optical effect and the stress intensities. If, for example, we take two tension members and subject them to the same uniform stress intensity the colour effects produced by interference will be precisely the same for each, while if they are superposed to interpose a double thickness the colour effect is that produced on a single member under twice the stress. Experiments on three or more superposed members readily verify for simple tension and compression that the optical effect is simply proportional to the stress intensity, and also to the thickness of the plate. If, however, two equally stressed tension members of the same thickness are crossed, as shown in Fig. 30, the common area gives a dark field, showing that the stress effect of one neutralises that of the other. The same dark field is produced if an equally stressed compression member is placed with the direction of stress parallel to that of the tension member Fig. 31, and we may readily verify in all cases that tension and compression stresses in the same direction add their effects, while stresses in directions at right angles subtract them.

The latter result is of chief importance because the stress at any point of a plate can always be represented by two stresses p and q at right angles, and their optical effect is proportional $p-q$. The value of the stress difference may therefore be determined by matching the optical effect produced at the given point with that produced on a simple tension or compression member, or, better still, by reducing the optical effect to zero by a simple tension or compression member set along one of the directions of principal stress, and stressed until a dark field is produced. In many cases of practical importance, such as occur in beams and columns, one of the stresses q is zero, and the stress distribution in a model is readily determined without further measurement, but in the majority of practical cases the magnitude of q is comparable to p and each must be determined.

(To be continued.)

THE SOCIETY OF ENGINEERS.

AT a meeting of the Society of Engineers (Incorporated), held on Monday, February 2nd, the premiums awarded for papers published during 1913 were presented, and the President for 1914, Mr. H. C. H. Shenton, delivered his Presidential Address. The immediate Past-President, Mr. Arthur Valon, M.Inst.C.E., presented the premiums as follows: The president's gold medal to Dr. Eric K. Rideal for his paper on "The Corrosion and Rusting of Iron." The Bessemer premium, value £5. 5s., to Mr. Bernard L. Rigden for his paper on "The South-Eastern Coalfield." The Clarke premium, value £5. 5s., to Mr. Gerald O. Case for his paper on "Accretion at Estuary Harbours on the South Coast of England." A Society's premium, value £3. 3s., to Mr. Wm. Yorath Lewis for his paper on "The Tram *v.* Bus Controversy."

Mr. H. C. H. Shenton was then installed as President and delivered his inaugural address, which he opened by referring to the need for better organisation of the engineering profession and the consideration that the society was giving to the subject with a view to promoting the well-being of the engineer. They were not arrogating to themselves a right that belonged equally to other engineering societies, but were endeavouring genuinely to increase the interest of engineers in a movement for the advantage of the profession, and the society was willing to support well-considered efforts that others might make in this direction. He therefore urged that all engineers, whether members of the society or not, should give any assistance they could, by bringing to the notice of the Council matters pertaining to the organisation and betterment of the profession, and by friendly co-operation when possible. An enormous amount of public money was wasted annually in connection with engineering works that were designed and carried out by untrained or inadequately trained men, and it was necessary in the public interest that engineers should combine in an endeavour to prevent engineering works being entrusted to those who were not competent to advise properly on such matters. It appeared, moreover, that anyone might pose as an authority and write a text book for the use of students, a proceeding that was grossly unfair to the learner and a probable source of error for the unwary. Some text books that were published were little more than advertisements for some one type of apparatus or process, and in effect were misleading because they entirely ignored other equally useful machines or methods. Some form of censorship seemed desirable for books that were to be placed in the hands of engineering students. The system that now obtained, by which complete designs for works could be obtained free of charge from manufacturing firms, was not only unfair to the manufacturer and to the consulting engineer, but to the public, who eventually had to pay for the designs that were made but never used. The address concluded with a detailed reference to recent developments in connection with water supply and sewage disposal.

Oil for the Navy.—The Admiralty have, we learn, just concluded an extensive contract with certain of the Scotch oil companies for a large quantity of liquid fuel, and Scotch companies have been extending their plant to meet the naval requirements.

GAS POWER FOR COLLIERIES.

Two papers devoted to a consideration of gas engines for use at collieries were read at a meeting of the Midland Institute of Mining, Civil, and Mechanical Engineers, held at Sheffield, on the 27th ult. The first paper by Mr. A. T. Cocking, of Messrs. Kynochs, Ltd., dealt with "Modern Gas-engine Practice for Collieries." The author said that the possibility of generating gas from waste fuel purposely left in the mine, or picked out as useless in sorting the coal, must now be recognised as a means of supplying most, if not all, power required for the work of a colliery, and this source of power, added to that recoverable by utilising the gases generated in coking coal, pointed to the probability that in the near future a modern colliery would be in a position, not only to generate its own power without using its saleable fuel, but would also from the same source supply electrical current to neighbouring factories for power, or to townships for light; and, taking into consideration the unique advantages which a colliery possessed in having its saleable fuel at first cost, it was not an extravagant prediction to say that in the future, by means of a judicious blending of the cheaper kinds of its saleable fuel with its available waste, and by the full use of the products of its coking plant, an up-to-date colliery would become a great power generating centre, the revenue from which would be the predominating factor in its profits. In a comparison of the relative costs of power generated by gas engines and by steam engines, he estimated that at a colliery using, say, 3,000 h.p., probably five tons of coal per hour (or 36,000 tons per year) would be burned in Lancashire boilers to raise its steam, and at a value which may be taken at 5s. per ton (for the sake of fixing a value) this would represent in a year £9,000 in fuel. Allowing 1lb. of the same fuel for each horse-power hour in a gas-power plant, the consumption would be 1·34 tons per hour, or 9,643 tons per year, the value of which at the same rate would be £2,410 per year, thus effecting a saving of £6,600 per year by using only 26¾ per cent. of the fuel used in the old way, and a set off against this cost of fuel would be the profit on the 300 tons per year of ammonium-sulphate which could be recovered from it.

The other paper by Mr. T. C. Wild, of the National Gas Engine Company, dealt with "the development of the gas engine in England and its adaptation to the generation of power at collieries and ironworks." He said it was only within the last ten years that the prejudice which formerly made the British colliery owner averse to erect by-product coke ovens, and the British iron master to make use of coke produced in them, had been overcome, and in the same way the application of surplus gas for power had not advanced to the same extent in this country as on the Continent and in America. In the matter of reliability the gas engine was proved to hold its own, the percentages of breakdowns being, in the case of steam engines one in 8·1, electric motors one in 8·2, and gas and oil engines one in 12·4. Mr. Wild described a number of big installations, the experience of which he maintained proved that collieries which had by-product coke ovens possessed a source of power in the surplus gas which might enable them to reduce their colliery consumption very materially; that a large quantity of refuse material, now tipped to waste, could be utilised in gas producers, either in cases where there were no by-product coke ovens, or where the material was unsuitable for coking; and that modern gas engines were now as reliable as steam engines, and much more economical.

Ball Bearings for Line Shafting.—Some tests have recently been carried out at the works of Messrs. Alfred Herbert, Ltd., of Coventry, to ascertain the comparative efficiency of ordinary and ball bearings for line shafts. The tests showed that 5½ h.p. (22 amperes at 220 volts, motor efficiency 85 per cent.) was required to turn over 62ft. length of 2¼in. shafting, running without belts in seven adjustable self-oiling bearings, with two ring oilers to each bearing. But in their new factory, where ball bearings are fitted to all the shafts, only 2½ h.p. was required to turn a shaft of the same length, with all pulleys on but no belts. On this shaft there were seven ball bearings placed at 10ft. intervals.

INDUSTRIAL AND TRADE NOTES.

Clyde Shipbuilding.—During the past month there were launched from Clyde shipbuilding yards 11 vessels of 22,272 tons. The output is about up to the average for the month.

Tin Output in the Malay States.—The Malay States Information Agency states that the output of tin from the Federated Malay States in 1913 amounted to 50,128 tons, as compared with 48,250 tons in 1912, and 43,967 tons in 1911.

German Pig-iron Production.—According to the "Frankfurter Zeitung," pig iron supplies at the end of December last amounted to 613,000 metric tons, against 507,000 metric tons at the end of November, 1913, and 247,000 metric tons at the end of 1912. The amount of pig iron produced during last year was 19·29 million metric tons, against 17·87 million metric tons in 1912.

Iron Ore and Petroleum Production of the United States.—The estimated production of iron ore in the United States is given by E. F. Burchard, of the United States Geological Survey, as between 58 and 60 million gross tons. The largest previous output was 57 million tons in 1910. The estimated figures for petroleum production, given by Mr. D. T. Day, of the United States Geological Survey, are 240 million barrels, or about 32 million metric tons, as compared with slightly over 222 million barrels in 1912.

Belgian Pig-iron Production.—According to the "Frankfurter Zeitung," the production of pig iron in Belgium amounted to 2,146,700 metric tons in 1913, an increase, as compared with the previous year, of only 168,000 metric tons, although the number of blastfurnaces increased from 54 to 59. In the first half of the year, during which period the prices for finished products had already dropped, prices of pig iron were comparatively favourable, but during the latter half of the year, owing to industrial depression and the growing demand for foreign pig iron, prices sank in a very marked degree.

High-speed Telegraphs.—The Postmaster-General has appointed the following committee to enquire into systems of high speed telegraphy and to report thereon: Captain Norton, M.P., Assistant Postmaster-General, chairman; Sir John Gavey, past president of the Institute of Electrical Engineers; Mr. John Lee, traffic manager of the Post Office Telegraphs; Mr. W. M. Mordey, past president of the Institute of Electrical Engineers; Mr. A. M. Ogilvie, third secretary, General Post Office; Mr. W. Slingo, engineer in chief, General Post Office; and Mr. W. B. Walkley, assistant secretary, General Post Office.

Electric Traction in the United States.—According to figures published in the "Electric Railway Journal," the total mileage of new track for electric traction built in the United States during 1913 was 1,019, which includes interurban lines, street railway, and electrified steam roads. This figure compares with 950 miles in 1912, 1,191 miles in 1911, and 1,397 miles in 1910. Rolling equipment ordered by electric railways during the year 1913 amounted to the following totals: City cars, 3,820; interurban cars, 547; freight and miscellaneous cars, 1,147; electric locomotives, 68. Last year's figures for the same equipment were: City cars, 4,531; interurban cars, 783; freight and miscellaneous cars, 687; electric locomotives, 65. The total number of cars of all classes built in company shops last year was 772, as compared with 429 in 1912.

Steel Trade Amalgamation.—The Steel Company of Scotland propose to acquire a half interest in the Appleby Iron Company, Scunthorpe, Lincolnshire, the other half interest being held by the Frodingham Iron and Steel Company, Scunthorpe. A large supply of ironstone is available, and it is proposed that the Appleby Company should, in addition to carrying on and extending their additional works, construct on an adjoining site new works for the manufacture of steel plates by the basic open hearth process. A provisional agreement has been entered into. It is proposed to increase the capital of the Appleby Company to £800,000, of which £175,000 will be held by the Frodingham Company, and £175,000 by the Steel Company of Scotland. The Steel Company's share capitalisation is £500,000.

British Gas Undertakings.—According to "The Gas World," there are 1,237 gas undertakings in England and Wales, 260 in Scotland, and 110 in Ireland. Of the total in England and Wales, 1,004 are owned by companies and only 233 by local authorities, in Scotland 199, against 61, and in Ireland 84, against 26. The annual make of gas in England is given as 195,787 million cubic feet, in Scotland 19,007 million cubic feet, and in Ireland 5,947 million cubic feet, making a total of 220,741 million cubic feet (as compared with 210,499 million cubic feet in the previous year), and this was distributed amongst 7,333,401 consumers. Of the total municipal gasworks supplied 35·8 per cent. of the total quantity among 38·4 per cent. of the consumers. Of the gas made in

Scotland 83·8 per cent. is made in municipal gasworks, while in England only 30·6 per cent. is so made, and in Ireland 51·4 per cent. The greater London companies produce almost exactly 25 per cent. of the output of gas for the whole kingdom, and supply 20 per cent. of the gas consumers.

Roller Bearings.—The Hoffmann Manufacturing Company, Chelmsford, send us a circular of a roller bearing they have just put on the market, after having been subject to trial under severe conditions for several years. The great trouble with roller bearings hitherto has been the incidence of end thrust, which once it begins to arise tends to increase, and often becomes so aggravated that the friction is greater with the roller bearing than with one of ordinary type. This difficulty, the firm state, is entirely obviated in the bearing shown by the extreme accuracy of the rollers and races in which they work. The rollers are of the short type, the length being not greater than the diameter. There is undoubtedly a wide field of service open to a satisfactory roller bearing on account of its high load carrying capacity. The firm claim to have solved the problem. They say they are able to offer to engineers a roller bearing of great strength which will run practically at any speed—they are regularly being used on woodworking spindles running at 8,000 revs. per minute to 9,000 revs. per minute—and which does not develop end-thrust.

Industrial Fatigue.—At a meeting of the Newcastle Economic Society, Mr. J. W. Ramsbottom, Lecturer in Economics at Armstrong College, gave an address on "Industrial Fatigue." The subject was, he said, one of exceedingly great importance and exceedingly difficult, for it presented problems to three branches of science—physiology, psychology, and economics. Experiments had shown that speeding up beyond a certain limit was excessively fatiguing, and it showed itself in a much more proportionate increase in the number of inaccurate movements—inaccurate movements which might result in accident. He thought, therefore, one might ascribe some of the increase in reported accidents in the last two or three decades largely to the increase of speeding up operations. The number of accidents in the first hour of work was relatively low, and rose to the maximum after three hours' work, and this order was repeated after the interval, showing the influence of the mid-day meal. The conclusion was that the occurrence of accidents was in a considerable degree determined by fatigue, and that if the working day were shorter or better split up the number of accidents would be considerably reduced. The general period of the working day at present was too long, and there must be chronic overstrain in the majority of industries. This did not necessarily imply an approach of an all-round eight hours' day. It might be that in some industries or operations a day of nine hours might reasonably be obtained, whilst in others a day of six hours might be too long.

Fi e Protection at Sea.—According to "Safety Engineering," during the last seven and a half years 155 steamships have been totally, and 2,447 partially, destroyed by fire. From these figures it seems clear that the ordinary fire precautions at sea are not sufficient. As a rule they rely on human observation, and are only brought into operation when the fire has become evident, and when it is often, therefore, dangerous. To secure absolute safety requires the use of automatic extinguishing apparatus. Such apparatus, in the form of the "Grinnell" automatic sprinkler and fire alarm, has been in successful use on land for a number of years, and there seems to be no good reason why it should not be similarly employed at sea. The "Grinnell" system is simple and sure, and there is no doubt its general adoption on ships would increase the safety of sea travel. Technical difficulties in the way of protection of ships with automatic sprinklers may be said to be non-existent, and as a matter of fact a number of ships have been fitted with them. As long ago as 1907 two vessels belonging to the New England Navigation Company were so fitted, while amongst others the Hamburg-Amerika liners the "Imperator" and the "Vaterland" are now being equipped with "Grinnell" installations. Only a few weeks have elapsed since the occurrence of the fire tragedy on the "Volturno." There is little doubt that an automatic fire extinguishing installation would, in this case, have saved many lives and much valuable property.

Zinc Industry in Japan.—From information supplied by the Acting British Consul-General at Kobe, it appears that zinc mines in various districts of Japan are worked by the aid of foreign capital and the ore produced is exported. While Japan is rich in the raw material, comparatively little actual refining is done in the country, chiefly owing to insufficient funds and lack of technical skill. At present the only concern in Japan conducting this industry in a comparatively methodical manner is the Osaka Zinc Mining Company, which produces 250 tons of refined zinc a month and contemplates being able to produce 4,500 tons during 1914. The company commenced to manufacture experimentally four years ago, and as the result of continued hard work and investigation at last reduced the business to working order. The company possesses mines at Marukura and Kagasawa in Echigo, and at Misaka in Echizen, and in addition to this it possesses stocks of ore in various districts, so that it has an ample supply of raw material. The Mitsui Company of Tokio is shortly to commence zinc refining at Miike, where it will make use of the cheap coal available there, importing the zinc ore from Hida and Kamioka. Now that the zinc industry in Japan is on the point of passing from the transition period, not only will the imports (to the value of about £289,000 in 1912) be completely checked within a few years, but there is, perhaps, a risk of an over-supply when the two works are completed. It is reported that in consequence the two companies are negotiating together and are planning the development of the galvanising industry as a method of preventing this over-supply.

Cost Accounts and Depreciation.—At the Applied Science Department of the University of Sheffield, on the 26th ult., Mr. M. Webster Jenkinson, F.C.A., read a paper before the Society of Metallurgists and Engineers entitled, "Some Principles of Accounting Affecting Cost Accounts." He emphasized the necessity of accurate cost-keeping, and the application of proper principles of accounting in calculations of productive cost. Without accurate cost records, the lecturer maintained that no large commercial undertaking could now be conducted on a sound financial basis. Cost accounts not only showed the cost of production for the purpose of fixing selling prices, but also indicated the respective advantages of hand and machine labour and the merits of various processes. The main object of any system of cost accounts was to show the prime cost or cost of production so that the manufacturer may know either the profit and loss on a job, or the selling price to be charged. The secondary objects were to obtain reliable records of work done for future reference, to detect waste of material or time, to provide a check on managers, and to enable periodical returns to be prepared showing the progress of the business. The lecturer dealt at some length with the question of depreciation, remarking that in many concerns this calculation was made by rule of thumb. He defined depreciation as the diminution in the value of an asset due to wear and tear or exhaustion of subject matter, natural causes occasioned by the effluxion of time, and obsolescence owing to inventions and the general progress of mankind. It was to be feared that English manufacturers did not provide sufficiently for depreciation, and, consequently, were often unable to keep their plant up-to-date. In this respect the Americans were far ahead of our home manufacturers. They were able to scrap their plant without financial embarrassment, and get orders in spite of higher wages.

The World's Shipbuilding in 1913.—Record shipbuilding figures were established during 1913, not only by the United Kingdom, but by the rest of the world. The annual summary of Lloyd's Register, just published, gives the following figures in comparison with the two previous years:—

	1911.	1912.	1913.
United Kingdom	2,034,630	1,930,251	2,203,529
Other countries	1,384,379	1,506,147	1,806,262
World's output	3,419,009	3,436,398	4,009,791

Taking merchant tonnage only, the United Kingdom launched 58 per cent. of the total world's output last year, compared with 60 per cent. in 1912, and 68 per cent. in 1911. During 1913, exclusive of warships, 688 vessels of 1,932,153 tons gross (641 steamers of 1,919,578 tons and 47 sailing vessels of 12,575 tons) have been launched in the United Kingdom. The warships launched at both Government and private yards amount to 49, of 271,376 tons displacement. The output in the United Kingdom showed an increase of 193,639 tons, exceeding the previous record (1906) by 104,000 tons. Nearly 78½ per cent. of the total output, or 1,513,107 tons, was built for registration in the United Kingdom. Steam tonnage increased by about 637,000 tons, and sailing tonnage decreased by about 55,000 tons. There was launched for other countries 419,046 tons. The number of large steamers launched greatly exceeded the average of recent years. There were 84 vessels of 6,000 tons and above, of which 21 were over 10,000 tons each, the largest being the Cunard liner "Aquitania," of 47,000 tons. Sixteen vessels launched in the United Kingdom are capable of a speed of 16 knots and above. The fastest are the turbine vessel "Aquitania" and two other turbine steamers. There was under construction at the end of December, 1,956,606 tons, 107,000 tons less than the record figures of March, though within 13,000 tons of the total building at the end of 1912. Outside the United Kingdom there were launched 1,193 vessels of 1,806,262 tons, divided thus: Merchant and other vessels, 1,062 of 1,400,729 tons; warships, 131 of 405,533 tons displacement. Merchant tonnage shows the very large increase of over 237,000 tons as compared with 1912, and constitutes a record. The principal countries built as follows: Germany, 465,226 tons (increase, 90,000); U.S.A., 276,448 (decrease, 8,000 tons); France, 176,095

increase, 65,000. Holland, 176,095; Japan, 64,664; Austria Hungary, 61,757; Norway, 50,637; Italy, 50,336; British Colonies, 18,339; Denmark, 10,932. As 682,000 tons of shipping were lost, broken up, &c., during the year, the net increase in the world's mercantile marine during the year was about 2,651,000 tons.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1912.

Lubricating the bearings of railway vehicles. Elsdon & Galle. 16539.
Apparatus for the hydraulic transmission of power. Jerrard. 22905.
Internal-combustion engines. Still. 28472.

1913.

Means for producing heat by the combustion of gaseous fuel. Gare. 652.
Combined governor and speed-setting device. Withers. 789.
Bulkheads of ships. Oswald. 900.
Roller bearings. Browne. 1056 and 1057.
Manufacture of manganese bronze. Heusler and British Mining and Metal Company. 1092.
Gas producers. Whitfield. 1117.
Gas washers or tar extractors. Whitfield. 1118.
Wrenches. Jurkovich. 1146.
Variable-speed driving mechanism. Boon. 1154.
Brakes for railway wagons. Smith, Edwards, & Steward. 1185.
Water wheels. Ripson & Whitehead. 1214.
Portable gas generating plant and motor. Soc. Anon. Hongroise de Banque et de Commerce. 1309.
Hammer drills. Holman & Holman. 1609.
Rock drills. Holman & Holman. 1610.
Internal-combustion engines. Wolseley Tool and Motor Car Company, and Rowledge. 1953.
Engine valve-gear. Sigler. 2161.
Apparatus for supplying fuel to internal-combustion engines. Fothergill. 2252.
Gasification of fuels containing volatile constituents. Timm. 3672.
Brake apparatus for railway vehicles. Spencer. 4484.
Carburetters for internal-combustion engines. Wishart. 4567.
Fuel supplying means for internal-combustion engines. Gardner and Gardner. 6237.
Carburetters for internal-combustion engines. Brewer & Jones. 6323.
Valve gear for pumps. Cockburn & MacNicoll. 7936.
Hydraulic clutches. Rich. 8026.
Apparatus for use in drawing wire. Gladitz. 8288.
Driving-gear of motor road vehicles. James & Robertson. 9416.
Means for propelling and steering ships. Blicharski. 9600.
Carburetter for internal-combustion engines. Martin. 9774.
Arrangement for automatically stopping pneumatic tools. Ateliers Leonard Rocour. 10128.
Process for fusing tungsten. Siemens Bros. & Co. 10369.
Furnace fire bridges. Prim. 10997.
Reversible motors. Becht. 11288.
Tunnel kilns or furnaces for tempering, cementation, and similar processes. Richter. 11632.
Valve devices. Wade. 12799.
Rotary engines or pumps. Christoph & Preiss. 12990.
Appliances for ensuring the safety of lift cages in case of breakage of the hauling ropes. Innerd & Young. 14597.
Brake mechanism for railway vehicles. Gresham. 15033.
Mechanical lubrication. York. 15352.
Nut locks. Williams. 15391.
Flywheels. Rothsten & Hooper. 15395.
Hydraulic packing. Vulcan Werke Hamburg und Stettin Akt.-Ges. 15638.
Gear shifting mechanism. Gray. 16012.
Wrench combined with other tools. Post. 16830.
Engines with one or more revolving pistons. Brauneis, Von Szaszy Neufeld, & Maitinszky. 17999.
Fuel for internal-combustion engines. Gulick. 18681.
Wrenches. Schlehr. 18758.
Chucks. Rohm. 19437.
Heat exchangers. Maybach. 19493.
Foundry moulding machines. Petch. 21194.
Means for reversing two-stroke internal-combustion engines. Munktells Mekaniska Verkstads Aktiebolag. 21389.
Air compressors. Craig. 21717.
Mixer for internal-combustion engines. Loose. 21820.
Fluid pressure reducing valve. Iliff. 22885.
Burners, for welding and cutting metals. Baechtold Strobel and Cartier. 23319.
Spanners. Lake, and Lake & Elliot, Ltd. 23793.
Vaporising or combustion chambers of hydrocarbon engines. Dawson & Livens. 25560.
Furnace for use in hardening, annealing, and tempering steel tools. Acres. 25799.

1914.

Turbines and centrifugal pumps. Jerrard. 45.

ELECTRICAL, 1913.

Starting and regulating devices for electric motors. Olmsted and Boothman. 745.
Apparatus for producing electricity. Meyers. 1098.
Electric vacuum-light apparatus. Moore-Licht Akt.-Ges. 1218.
Brush holders for dynamos. Von Zweigbergk. 1337.
Magneto-electric machines for combined ignition and illuminating purposes. Sinens. 1501.
Electric arc lighting. Pearce & Wilkinson. 6964.
Starting and regulating direct-current motors. Cumont. 7983.
Means for equalising or balancing electric currents. Railing and Garrard. 11905.
Trolley or collector wheels for electricity. Anderson. 17850.
Sparking plugs for electric ignition purposes. United Motor Industries, Ltd., and De Rodakowski. 20929.
Portable electric lamps. Neu. 22707.

METAL QUOTATIONS.

TUESDAY, FEBRUARY 3RD.

Aluminium ingot	90/- per cwt.
,, wire, according to sizes, &c. ......from	117/- ,,
,, sheets ,, ,, ... ,,	112/- ,,
Antimony	£28/-/- to £30/-/- per ton.
Brass, rolled	7⅜d. per lb.
,, tubes (brazed)	9¼d. ,,
,, ,, (solid drawn)	8½d. ,,
,, ,, wire	7½d. ,,
Copper, Standard	£66/5/- per ton.
Iron, Cleveland	51/4½ ,,
,, Scotch	57/4½ ,,
Lead, English	£20/10/- ,,
,, Foreign (soft)	£20/2/6 ,,
Mica (in original cases), small	6d. to 3/- per lb.
,, ,, ,, medium	3/6 to 6/- ,,
,, ,, ,, large	7/6 to 11/- ,,
Quicksilver	£7/10/- per bottle
Silver	26⅝d. per oz.
Spelter	£21/10/- per ton.
Tin, block	£183/-/- ,,
Tin plates	13/1½ ,,
Zinc sheets (Silesian)	£25/-/- ,,
,, (Stettin; Vieille Montagne)	£25/2/6 ,,

Lectures on Lubricants.—Mr. Lionel G. Radcliffe, lecturer in organic chemistry at the Manchester Municipal School of Technology, began on Thursday last week a course of ten lectures on the "Chemical Technology of Lubricants." The lectures are intended for engineers and others engaged in industries in which lubrication is of importance; also for persons engaged in the manufacture or sale of lubricating oils. Before dealing with lubricants the lecturer urged the importance of attention to friction in machinery. In many mills, Mr. Radcliffe said, to drive a shaft alone required from 20 to 30 per cent. of the useful work done by the engine, and sources of loss could be reduced by a more careful attention to the use of proper lubricants, and a knowledge of their manufacture and composition. A good deal of stuff was offered for use which might be termed retardants rather than lubricants. At first trial they worked well, but soon began to clog. Mr. Radcliffe then referred to the sources and properties of lubricants, and the distinction between mineral and vegetable oils. Incidentally he mentioned the increased demand for castor oil as a lubricant by airmen, who required something that would stick to the machinery despite the rapid movements of the propeller. In subsequent lectures he will, among other matters, deal with the chemical properties and methods of examination of lubricants, and the characteristics of individual oils used in blending lubricants.

The Mechanical Engineer.
AN ILLUSTRATED WEEKLY JOURNAL
Vol. 33, No. 838.

Edited by
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Telegrams: "Scientific," Manchester.
Telephone No. 6055 City.

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Advertisements, displayed, for insertion in current issue should reach our Manchester office not later than first post Tuesday morning, and small prepaid advertisements not later than first post Wednesday morning.

Accidents in Foundries.

A DEPARTMENTAL COMMITTEE appointed by the Home Office to enquire into accidents in places under the Factory and Workshops Act suggested that certain matters bearing on accidents in foundries should be made the subject of special enquiry, and subsequently discussed with representatives of employers and workmen engaged in the trade. This has since been done, and the results are set forth in a report by Mr. Gerald Bellhouse, H.M. Superintending Inspector for the South-eastern Division. The points round which discussion centred related to questions of lighting, the use of iron floor and gangway plates, the catching and carrying of metal from the cupola, the testing and examination of lifting tackle, and the protection of the feet of workmen from risk of burning by splashed metal. With the exception of the first and last of these points, both of which are important, while the last is associated with the greatest number of accidents, a pretty general agreement was reached by the parties concerned, so that there is not much likelihood of difficulty being experienced in carrying out the new foundry regulations it is proposed to embody in the Factory and Workshop Act of 1901. They will undoubtedly tend to greater safety, and there is no doubt that many accidents now occur in foundries which are preventable. One indirect but important contributory to them in many ways is defective lighting, but it was the one point on which no agreement could be come to, and on which the Home Office do not at present propose any definite regulation. Circumstances and available methods of lighting differ so widely that it is not easy to formulate definite rules, and, seeing that the whole question of factory and workshop lighting is being made the subject of special enquiry by a Departmental Committee, it is perhaps as well the matter should remain for the present in abeyance. As regards the use of iron plates for gangways and under the spouts of cupolas, the conference disclosed great divergence of opinion amongst the operatives themselves, as well as amongst the

representatives at the conference. This we can understand, for foundries differ widely as regards class of work dealt with, and, while a plate gangway may in one shop be a distinct advantage and conduce to safety by permitting of easy transportation of molten metal to various parts, it may in another case be a nuisance. There was, however, complete agreement in one respect, that where used such plateways should be kept dry, so as to avoid the explosive splash which occurs when molten iron is spilled on a damp plate. No exception also can be taken to a regulation which insists on a clear passage way of 18in. when there are rows of small moulding boxes to cast with a hand ladle, or which forbids boys under 16 years of age carrying molten metal. Equally reasonable is the regulation which in future will insist on all lifting chains being periodically annealed and tested and a register kept of all chains, containing the distinctive mark of each with its safe working load and the dates on which it was annealed or tested. Accidents with lifting tackle are generally serious and are far too many. The most frequent source is, however, burns, especially of the feet and legs, due to the spilling of hot metal in the process of catching it in ladles at the cupola, carrying to the moulds, or pouring it therein. There are few moulders of middle age who have not been burned in this way at one time or another, and few who have had experience of foundry work who will not admit that a great many of these burning accidents could be prevented by the use of proper foot gear. Ordinary laced boots when they become worn offer convenient openings for the entrance of a drop of molten metal if it happens to be spilled over the foot, and slight spilling is more or less unavoidable, and the result is a nasty burn that takes weeks, and sometimes even months, to heal. Clogs are worse than boots. How largely foot burns enter into foundry accidents is evident from the fact that out of 1,296 accidents due to hot metal in the period January to June, 1912, no less than 898 resulted in burns to the foot or lower part of the leg. Obviously the best protection against this class of accident is the wearing of special boots which do not provide openings through which metal can readily get inside, or of a covering in the shape of a flap or spat, but on this matter differences arose; the employers, while approving generally of such provision, thought the men should provide their own. On the other hand, the men, while admitting the value of such provision, objected to its being compulsory, on the ground that "if they did not use foot protectors they would be liable to penalties and to possible loss of workmen's compensation in case of injury." It is a curious attitude, and throws an interesting side light on the way in which workmen view precautions for their safety. We are glad the differences between the two parties have not prevented the Home Office taking definite action in the matter, and that in the new regulations it will be compulsory for adequate protection for the feet to be provided and maintained in proper order, and equally compulsory for every person employed in any part of a foundry where molten metal is caught, carried, or poured, to wear them. Such a provision, we are convinced from personal experience, will reduce accidents from foot burns to very small dimensions.

Nottingham University College: Scientific Exhibition.—In order to interest the public in the work of the University College, and also to raise funds for certain students' clubs and societies, a scientific exhibition with entertainments and a sale of work will be held in the College on Saturday, February 21st, from 3 p.m. to 10 p.m. Tickets of admission may be obtained gratis from members of the staff and from students, or on application at the College. All the departments of the College will be thrown open to visitors, and there will be exhibitions of educational and scientific interest.

ELECTRICITY IN MINES.

In the course of an address recently delivered before the North Staffordshire Institute of Mining and Mechanical Engineers, Mr. Robert Nelson (H.M. Electrical Inspector of Mines) stated that the 3-phase system of transmission and distribution possessed clear advantages over the one and 2-phase systems. The best system rested between the 3-phase system and the continuous-current system. Although with the same voltage of transmission the cables of a continuous-current system cost about 30 per cent. less than those of a corresponding 3-phase alternating-current system, the former system was one of limited range only. Continuous current for colliery work must be transmitted and distributed at the pressure at which it was generated, but the difficulty of sparkless commutation at high pressures limited the pressure of generation to but little above the limit of medium pressure defined in the General Regulations for Coal Mines, namely, 650 volts. Hence, if the necessity arose to transmit any considerable amount of power a greater distance than one mile, or thereabouts, the voltage limit just indicated operated against the use of continuous current. The 3-phase alternating-current system had the advantage that there was no upward limit of pressure for long-distance transmission, and the pressure could be transformed by apparatus without rotating parts to any pressure desired; for example, to medium pressure for use in motors and to low pressure for use in lamps and portable apparatus.

Comparing the respective merits of the continuous-current motor and the 3-phase alternating-current motor, he stated that the latter possessed the following advantages: (1) The first cost of a 3-phase motor was about 25 per cent. less than a continuous-current motor of corresponding size. (2) Three-phase motors were inherently of better mechanical construction than continuous-current motors, and therefore with equal care in design and construction were less liable to breakdown. (3) If 3-phase motors of the squirrel-cage type be used no complicated starting apparatus was required, and as such motors had no rubbing contacts carrying current, there was no possibility of sparking in normal working. (4) Three-phase motors had greater overload capacity than continuous-current motors. Hence to deal with a variable load a smaller motor was required on a 3-phase system than would be required on a continuous-current system.

Continuous-current motors, on the other hand, dealt better with a heavy load at starting, and could easily be arranged to run economically at widely varying speeds. Further, where space was limited, they were more adaptable, but nevertheless for general purposes they were, on the whole, inferior to 3-phase machines. In general, then, though each system had its merits, 3-phase working appeared to hold a substantial advantage over continuous-current working.

The practical requirements for safety in working electrical plant underground were briefly: (1) Strong metallic outer coverings for all apparatus; (*a*) to protect insulating material from abrasion; (*b*) to prevent accidental contact by persons with live parts; and (*c*) to prevent open sparking. (2) An efficient connection to earth for the metallic outer coverings. (3) Provision for automatically making a faulty circuit dead immediately leakage of current began to develop.

The complete enclosure of all live parts within substantial earthed metallic outer coverings was, he remarked, the best safeguard against every kind of electrical accident. Items (1) and (2) above, could as readily be provided for in continuous-current working as in 3-phase working. Item (3), on the other hand, could more conveniently be provided for in 3-phase working. To provide for cutting off the current automatically immediately leakage of current took place, it was necessary, under the simpler systems of automatic protection in use, to connect to earth the neutral (or mid-voltage) point of the winding of the generator or transformer which supplied the current. The neutral point of a 3-phase generator was more readily available than was the corresponding point on a continuous-current generator, namely, the mid-voltage point. This was an incidental advantage that 3-phase working enjoyed, but the determining factor in respect of automatic protection was the convenience of being able to use current transformers, and these were only available in simple form on alternating-current circuits. Although the 3-phase system of working was, on the whole,

superior to the continuous-current system, it was not beyond the range of possibility that some development, at present unsuspected, might reverse this state of affairs. The above conclusion should preferably, therefore, be stated in this way: With the appliances in present use 3-phase working appeared to possess substantial advantages over continuous-current working.

BOOK REVIEWS.

Marine Boiler Management and Construction. By C. E. Stromeyer, M.Inst.C.E. 9¼in. by 6¼in.; 410 pp. Fourth edition. Longmans, Green, & Co. Price 12s. 6d. net.

The issue of a fourth edition of this work is good evidence of its appreciation and of its established position in boiler literature. The book has been extensively added to and improved since its first appearance, and in this edition has been brought quite in line with current practice, while considerable additions have been made to the records of experimental data bearing on the strength of boiler structures which are scattered throughout the book. The chapter on boiler construction is particularly strong, and a study of it would be useful to any boilermaker or engineer-in-charge in connection with many little troubles that occur in practice during the actual work of construction, or which are developed by the pressure and temperature stresses when the boiler is put into service. To the boiler surveyor or inspector other sections dealing with the physics of heat transmission, the chemistry of combustion and corrosion, and the mechanics of design, will be not less valuable for the mass of information condensed in them. These comprehensive chapters are supplemented with Lloyds and Board of Trade rules for the construction of marine boilers, and some useful tables compiled from them which will also be appreciated in the drawing-office when questions of boiler designs or estimates are under consideration. The author has throughout discharged his task in a painstaking and exhaustive manner.

* * *

Arithmetic of the Steam Boiler. By Chas. T. Mason. New York: McGraw Hill Book Company. 7½in. by 4½in.; 225 pp. Price 4s. 2d. net.

The author states in his preface that "he claims no originality in the preparation of the material" beyond the arrangement and manner of presentation, and offers it merely as a compilation of arithmetical rules and formulæ applicable to steam boilers. This being so, it would be unfair to complain of shortcomings, though it is legitimate to point out that such an elementary treatment of the subject as is presented is not likely to attract a wide circle of readers, for those requiring to deal with boiler rules and formulæ usually want other information besides, and if it were restricted to this, it could be got much cheaper. To sum up our opinion of the book, it is elementary, limited in scope, and dear, and we can only recommend it to those to whom the first point is important and the last of little consequence.

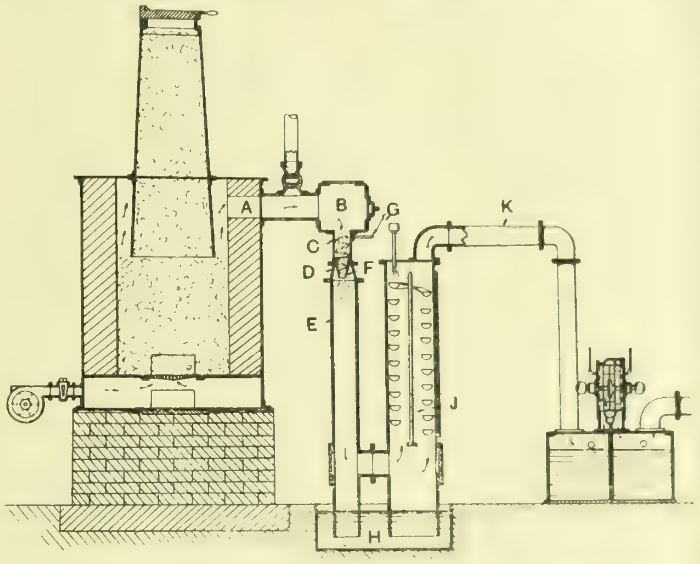
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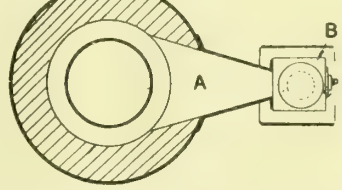
Coal Washing in Illinois, by F. C. Lincoln, of the Department of Mining Engineering of the University of Illinois, Issued as Bulletin No. 69 by the Engineering Experiment Station of that University.

This bulletin discusses briefly the theories of crushing, screening, and washing coals, followed by descriptions of the important types of coal-washing machines. Next come flow sheets and discussions of various Illinois washeries, supplemented by data relative to different phases of the work. The author visited many of the largest washeries in the States, and secured data covering costs and methods. This information has been embodied in a number of valuable tables, and shows the wide variance in cost and washing efficiency among the various plants. The bulletin is completed with an article on "Moisture in Washed Coals," by S. W. Parr, wherein is considered the retention of water by washed coals. The price of the bulletin is 50 cents, and copies may be obtained from Chapman & Hall, London.

WHITFIELD'S GAS PRODUCERS.

THE accompanying illustration show an arrangement of gas producer of the type designed to deal with light fuels, *i.e.*, fuels the non-gaseous and dust-like products of which are liable to pass with the gas and choke the passages leading to the point where the gas is required. This is especially so in the case of light fuels of a bituminous or tarry nature and where the producer is worked by the suction stroke of an engine. Attempts to overcome this objection have been made, chiefly consisting in washing out the dust after the gas leaves the producer. In the design illustrated, which has been patented by Mr. Charles Whitfield, of 16, Trewsbury Road. Sydenham, S.E., the dust is removed before the gas leaves the producer, or, in other words, the dust is left in the producer. The gas outlet A is of conical form in plan, as shown in plan. The junction box B is connected to the outlet, and from this box depends a short pipe C. Connected to this pipe at its lower end by a tapered connecting pipe D is a pipe E, this pipe being larger in diameter than the pipe C. Supported by a flange in the lower end of the pipe C is a conical nozzle F, the lower part of this nozzle extending into the tapered connecting pipe D. Fitted tangentially to the pipe C near its upper end is a water-supply pipe G. By means of this pipe water delivered therefrom flows in a





WHITFIELD'S GAS PRODUCER.

spiral path around the inner face of the pipe C, thereby keeping the same constantly washed and free from tar and dust. The lower and open end of the pipe E dips into a settling tank H. Near its lower end the pipe E is connected by branch pipe to a further pipe J, which at its lower and open end also dips into the tank H. At its upper end the pipe J communicates with the engine through a pipe K and a tar extractor.

The feature of the arrangement is the contraction of the passage for the gas by means of the nozzle F, whereby the action of the engine during each suction stroke is prevented drawing over the dust from the producer, the proportions of the nozzle being such that the suction of the engine has no appreciable pulsation effect on the bulk of the gas within the producer, and thus allows the dust to remain in a quiescent state, or nearly so, within the producer. The accumulated dust is removed in the ordinary course of stoking. By reason of the pipe E being wider than the pipe C, the gas and water pass straight down from the nozzle and there is thus little chance of any tar adhering to the pipe E. Within the pipe J is an open spirally-arranged channel supported by a central spindle resting on a cross-bar. Water is admitted into the channel through a pipe at the top. On its way to the pipe K the gas comes in contact with the water, and is thereby cooled and relieved of some of the tar, &c.

RECENT DEVELOPMENTS IN GRINDING MACHINES.

BY THOMAS R. SHAW, A.M.I.MECH.E.

THE cylindrical grinding machine is now regarded as essential in every workshop for reducing the cost of cylindrical work, but, notwithstanding the progress made in the last few years, it is surprising how many engineers fail even yet to grasp the possibilities that still exist in the substitution of grinding for older methods of machining. The majority labour under the impression that grinding is an additional operation in the creation of cylindrical work, and they have to turn work as they have always done, allowing something for the grinding machine to grind off to bring to size. But this is not the case. The modern grinding machine was originated to assist the lathe in producing cylindrical work, and to make the process less expensive than it was before any grinding was done—not simply to replace filing; that is why the grinding machine is so essential in modern engineering practice. Those who would produce cylindrical work efficiently must recognise the fact that different cases require different degrees of refinement, and whether the work requires a low or a very high degree of refinement, the lathe work, to be efficient, should be the same, viz., as rough and as cheap as it is possible to make it.

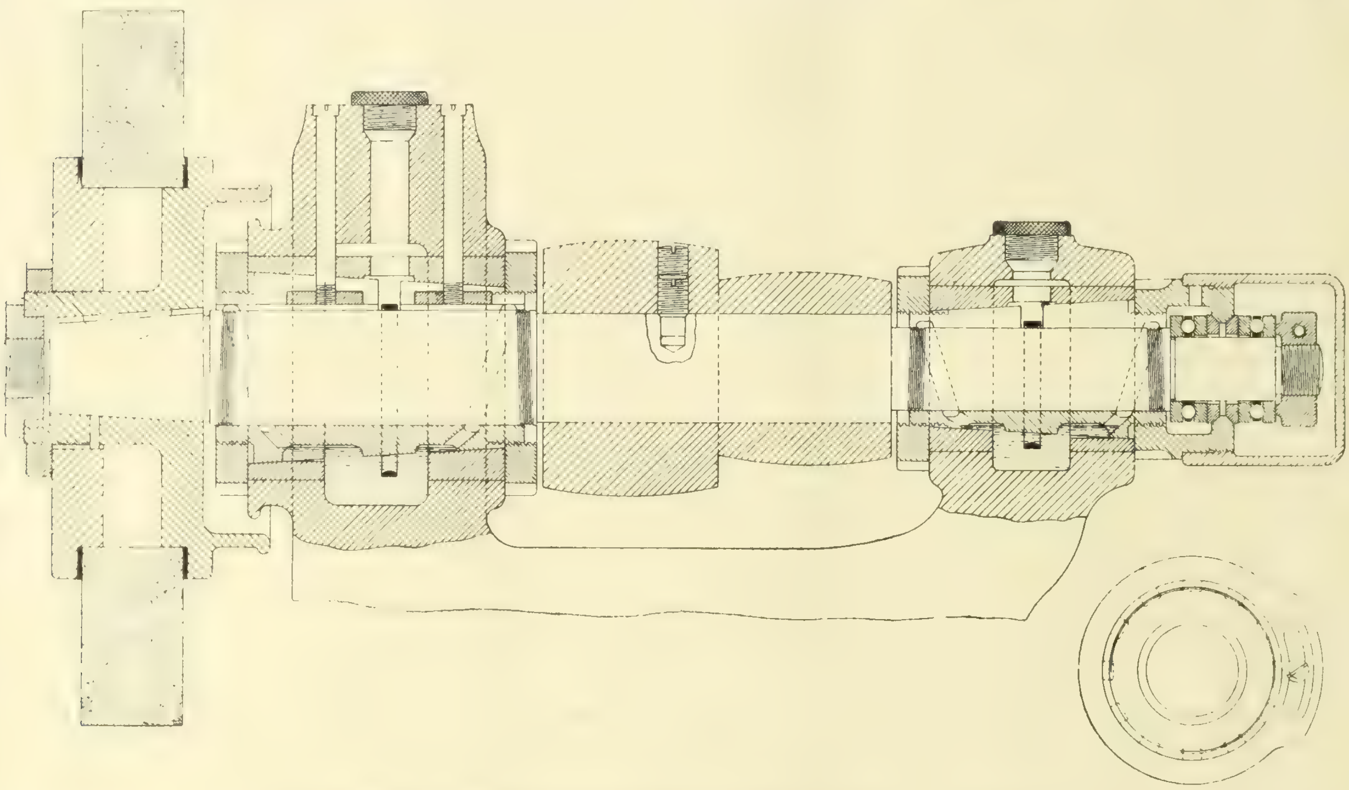


FIG. 1.—CHURCHILL GRINDING MACHINE SPINDLE, SHOWING METHOD OF OIL CIRCULATION.

The lathe to-day should be a roughing tool only, and the grinding machine a refining tool only, not a perfecting tool. Some grinding machines may produce greater refinement than others, but none can produce literally exact and perfect cylinders. While it is true many mechanics look upon a high degree of refinement as accuracy, and speak of it as such, it is easy to prove that it is not accuracy, but simply a high degree of refinement.

Diversified duties are now exacted from grinding, and machines are built to suit the varying requirements; plain machines for shafts, studs, pistons, crank shafts, &c.; universal machines for dealing with all classes of work; internal machines for grinding holes in cylinders, spindles, milling cutters, bushes, gears, ball races, &c.; surface grinding machines for flat surfaces of all kinds; special machines for work such as cams for gas and oil engines, automobiles; and machines for grinding by means of formers irregularly-shaped cylindrical pieces such as are used in ordnance and textile work.

The manufacture of grinding machines has usually been associated with America and Germany, and not until within quite a recent period has the manufacture of grinding machines, to any great extent, been carried on in this country, but in 1905 the specialised manufacture of precision plain and universal grinding machines was commenced by the Churchill Machine Tool Company, Ltd., Manchester, and they have so developed this business that to-day there is no necessity to go abroad for a grinding machine fully up to date.

The Churchill grinding machines cover a very wide range of sizes and types, and the purpose of the writer is to bring before the notice of our readers some of the various interesting features of these machines. They have found so much favour among operators that they are in use in every branch of the engineering industry, having been adopted in ordnance works, motor-car, electrical, textile, and general engineering works. The sizes of plain grinding machines now regularly manufactured and standardised range from small machines to grind 4in. diam. by 24in. long to large machines to grind 40in. diam. by 240in. long between centres. Being built in a works devoted solely to such manufacture, the result is that these machines possess distinctive features peculiar to themselves, and no effort is spared to continually improve them and keep them in the front rank. The type of machine built is that with a travelling work table and stationary wheel head, which, experience has proved, possesses a decided advantage in allowing immediate control of the grinding wheel. Experience has demonstrated that in a grinding machine of this character a travelling work table properly designed and accurately finished naturally assists in continuing the accuracy of the machine. It is a well-known fact that a lathe carriage, although every precaution in design be taken, will eventually wear the ways untrue, due to the carriage engaging but a portion of the ways during most of the time. This is also true of a milling machine where the table is longer than the saddle, the continual use on the machine of short work soon causing perceptible binding of the table on the ends, providing the gibs are properly adjusted.

One of the principal features aimed at in the Churchill grinders has been simplicity of operation, and every care has been exercised to give centralised control of all operating handles.

The body of all machines up to 10ft. between centres rests on three feet, and ribbing inside the body is in the form of a bridge, to give maximum rigidity.

Stability is an essential feature in all large machines, also that the bearings be wide and provided with efficient lubrication, and to this end the pressure per square inch on the sliding ways is, even when carrying the heaviest weights, kept very low. To facilitate lubrication of the slides, a special oil channel is provided at the side of the vee and flat respectively. This holds a large quantity of oil, and is connected to all the

oil pockets on the sliding ways, so that these can be kept constantly full of oil, and cannot by any means run dry. Steel oil rollers carried on spring bearings are fitted into each oil pocket, and the outer edge of the vee and flat ways respectively is raised above the actual bearing portion so that oil cannot escape, and is of necessity forced to run back to the oil wells, ensuring constant circulation.

Rigidity is another essential in a grinding machine. Accuracy and good finish are impossible if there is the slightest vibration. Few machines employed for fine work have more unfavourable conditions to contend against. The rapidly-revolving wheel and work and the abrupt reversal of the table at the ends of its traverse are all conducive to vibrations, which are further augmented by the cutting action of the wheel. When speeds and feeds are increased and heavier cuts taken in order to fulfil production requirements, it is evident how great is the need of perfect stability and rigidity. Special attention has been paid to the design of the spindle. This When wear takes place these pads are slackened by unscrewing the screws which hold them (they are not taken out) and, after the bush has been closed in by means of drawing it into the taper, the pads are once again drawn up tightly into place. A section through one of these spindles and bearings is given in Fig. 1.

A special and very important feature of all Churchill grinding wheel spindles is the method of preventing oil from leaking from the bearings. This is in the form of a fine vee thread which is cut on the spindle at the extreme end of each bearing, this thread being so arranged that the direction of the rotation of the spindle tends to force the oil into the bearing, and so prevents leakage and creeping of oil along the spindle.

The arrangement of wheel feed is by worm, worm wheel, and rack and pinion, as shown in Fig. 2. This construction confines the parts which may be subjected to the effects of torsion into a small compass, and enables the wheel to be

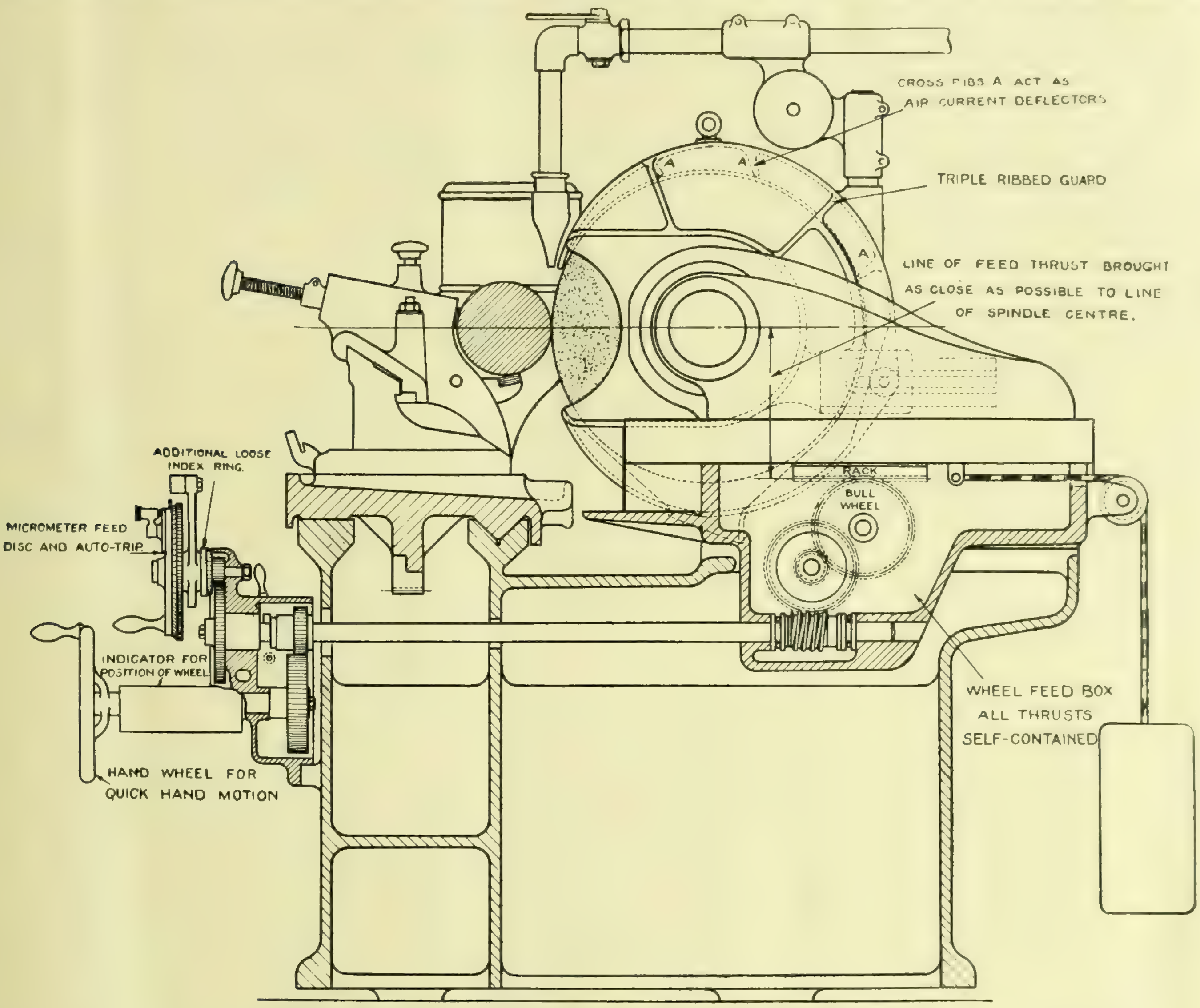


FIG. 2.—CROSS-SECTION OF GRINDING MACHINE, SHOWING THE PRINCIPAL ELEMENTS.

runs in parallel bearings with split taper bushes adjustable by means of fine thread nuts at either end. The spindle is held at one end by means of a double ball thrust bearing. This construction allows the spindle freedom to expand endwise without affecting the adjustment. It has been found that split taper bushes have a tendency to close in on the spindle at the point of severance, independent of the action of drawing in by means of the adjusting nuts. This is an objectionable feature in the spindle of a grinding machine, as it is essential to the true and steady running of the wheel that a uniform fit is maintained all over the surface of the bearing. To counteract this tendency the top part of the bush is provided with a dovetailed slot into which are fitted two dovetailed steel pads. These are held in position by cheese-head screws which, after the bearing has been finally adjusted, are drawn up tight; the action of the inclined faces of the pads causes the split bush to be forced apart at this point, and prevents any tendency to close too tightly on the spindle.

brought up to the point governed by the trip motion, without variation as is essential in repetition work. Another feature is that the thrust is self-contained in the wheel slide which carries the wheel head. On large machines it is possible by using this construction, and incorporating an intermediate or bull wheel between the rack and pinion, to bring the line of thrust close to the wheel spindle centre, thus eliminating any tendency for the head to be tilted by the thrust of the cut. The feed mechanism is thus as sensitive and accurate as on small machines.

Fig. 3 shows the arrangement of the automatic feed to the grinding wheel used on the smaller machines in order to put on an increase of cut at each end of the travel of the table. This is obtained from a spring plunger under the table reversing lever, which is depressed at the end of each stroke of the table, and the lower end of the plunger acting on the end of a bell-crank lever causes this to oscillate, and thence through a connecting rod and another bell-crank lever, motion

is transmitted through a pawl to a ratchet wheel keyed to a shaft passing through the body to the worm under the wheel head. The amount of feed is regulated by moving the end of the connecting rod on the bell-crank lever, which is graduated to show the amount. As it is operated by the

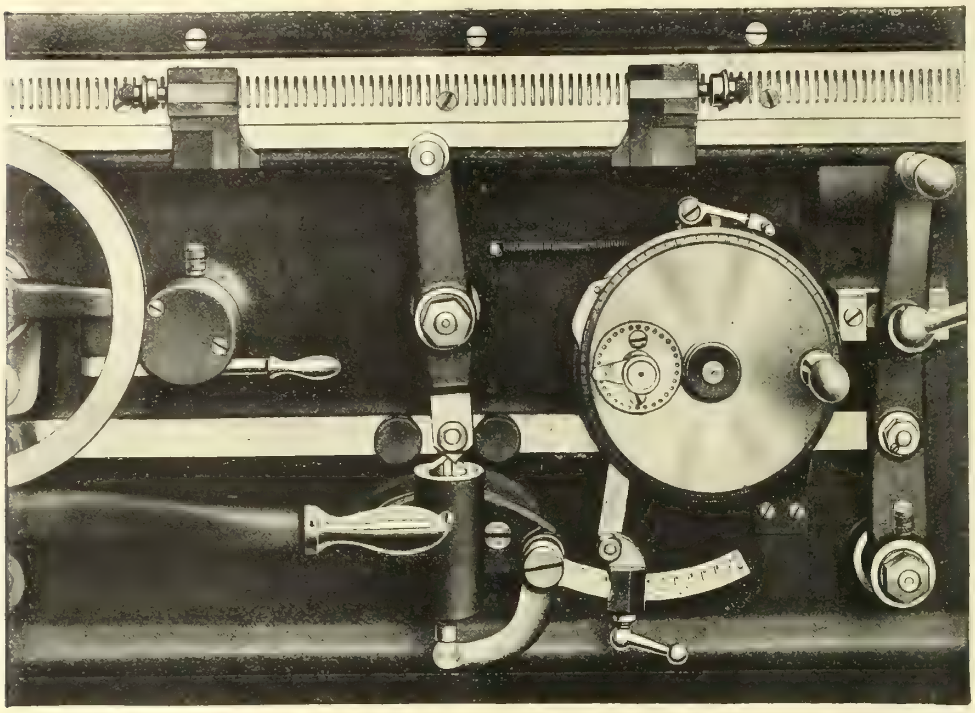


FIG. 3. OPERATING MECHANISM OF SMALL-SIZED GRINDING MACHINES.

plunger used for reversing, the amount of feed is not affected by any alteration in the length of stroke.

The ratchet pawl can be automatically thrown out at any desired point by means of a projection on a plate which travels with the ratchet wheel. Provision is made so that this trip plate can be set very quickly to an index, and a further refinement allows the trip to be set a little forward or backward accurately by turning the small knob with a little crank seen on the front plate of the ratchet wheel. This makes it possible to grind duplicate pieces to within ·00025in. diam. to any predetermined size. The holes in the small index plate are

to and from the work. It is an axiom that anything which will add to the convenience and ease of operation will add to the increase of production.

One of the most frequent sources of loss is the idle movements of the machine, another is the time spent in making adjustments between cutting operations. Now in grinding it frequently happens that there are considerable variations of diameter in pieces which require to be finished, and, as will be readily understood, the cross feed of the grinding wheel must be very fine on account of the work it is called upon to do. On the other hand, this fine feed becomes a time loser when it is necessary to transfer the wheel from a large to a smaller diameter of work, or vice versâ. The above device was therefore designed to overcome this. It adds to the convenience of the operator, and, in addition, an indicator shows the exact position of the wheel in relation to the work.

The automatic traverse of the table is controlled by adjustable dogs on the front of the table. The dogs, which are shown in Fig. 3, slide on a steel rack fixed on the table, and their position can be changed when the machine is running by simply pressing a thumb latch which engages with the rack, thereby releasing the dog and allowing it to be moved at will. There is also a fine adjustment provided on the dog in the form of a thumb nut and screw, so that the movement of the table and work can be regulated to a very fine degree, which is invaluable when grinding up to a shoulder.

The reversing mechanism is operated through a quick-acting spring plunger and is very exact. Interposed in the table gearing is a friction slip clutch which absorbs shock even when running at a high speed. By this means the Churchill grinders have a table speed far higher than that of any of the American machines.

On all sizes of machines the work and table speeds are independent of each other, which makes it possible to utilise the full width of grinding wheel by arranging the speeds so

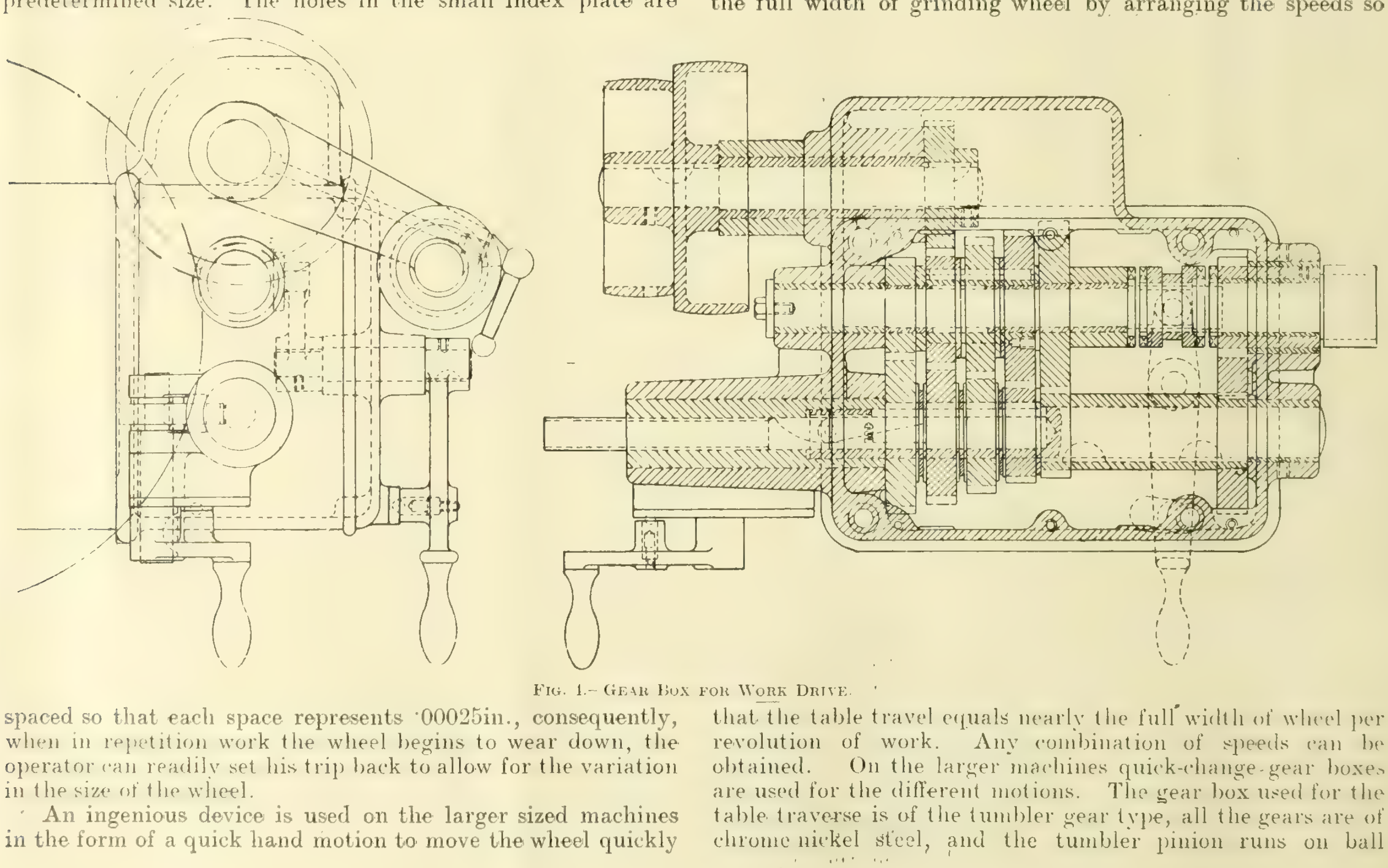


FIG. 4.—GEAR BOX FOR WORK DRIVE.

spaced so that each space represents ·00025in., consequently, when in repetition work the wheel begins to wear down, the operator can readily set his trip back to allow for the variation in the size of the wheel.

An ingenious device is used on the larger sized machines in the form of a quick hand motion to move the wheel quickly

that the table travel equals nearly the full width of wheel per revolution of work. Any combination of speeds can be obtained. On the larger machines quick-change gear boxes are used for the different motions. The gear box used for the table traverse is of the tumbler gear type, all the gears are of chrome nickel steel, and the tumbler pinion runs on ball

journal bearings. The gear box for giving the speed changes to the work is mounted direct on the headstock. This is of a different construction, as shown in Fig. 4. The box itself forms an oil bath and is all enclosed. Four speed changes are obtained through a sliding spring key, and this number is doubled by means of a double gear with a clutch between. The speeds are again doubled by the use of the two-speed cone pulley which drives the box, and to maintain an efficient tension on the belt there is a tension pulley.

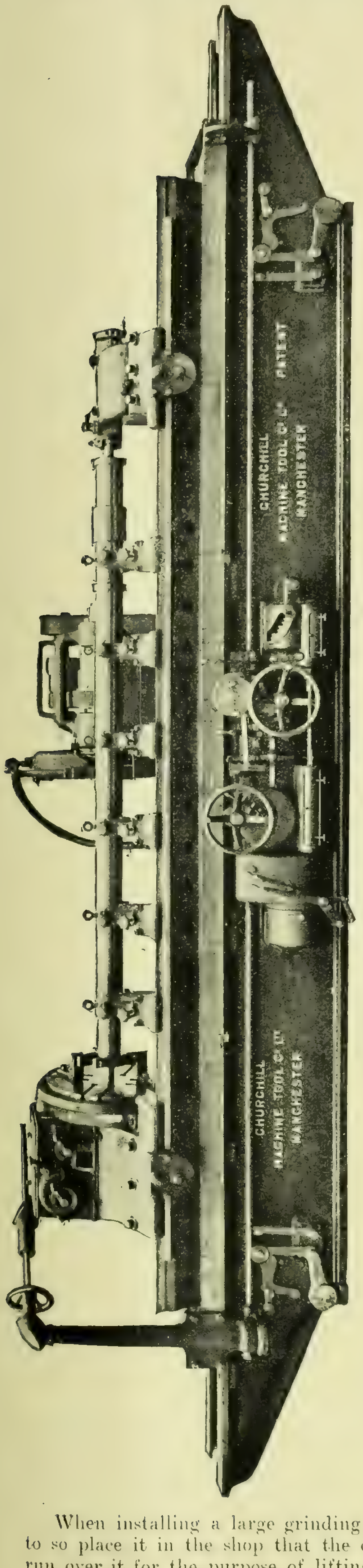


FIG. 5.—MASSIVE PLAIN GRINDING MACHINE. SWINGS 36IN. DIAM. AND ADMITS 16FT. BETWEEN CENTRES. Constructed by the Churchill Machine Tool Company, Ltd., Manchester.

It is obvious that with a cone pulley drive some sort of overhead gear is required. This is usually obtained from a drum, either carried on the ceiling or by pillars at the back of the machine. Such an arrangement becomes very objectionable on long machines, and the drum, being comparatively small in diameter, does not transmit the maximum amount of power as is necessary on large machines. On this account the Churchill Machine Tool Company have recently patented a new method of driving by means of an endless belt, which, besides doing away with the overhead gear, is more powerful and efficient. The belt in this case is driven from a shaft at the back of the machine, and then over guide pulleys through a large diameter pulley, on the work head gear box, which takes the place of the 2-speed cone pulley shown. The belt travels to and fro with the table. It is so arranged as to allow for the table being set to grind taper when desired, and can be instantly stopped by a lever placed in a convenient position on the front of the machine.

When installing a large grinding machine it is desirable to so place it in the shop that the crane may have a clear run over it for the purpose of lifting the work in and out. To this end, large machines should be entirely self contained, and preferably driven by motor. Such a machine is illustrated in Fig. 5, which is interesting as showing to what extent grinding machines are at present developing. This machine is probably the largest machine of its class that has yet been built, and is at work in one of the large engineering works in the neighbourhood of Manchester. The drive is so designed that all motions of the machine are obtained from one shaft, to which it is only necessary to couple the driving motor. One half of the coupling is shown in the end view of a machine in Fig. 6. In this machine the work head gear box is arranged with 16 speeds, and is of the sliding gear type, the gears being on fixed centres, and only those gears actually in use are in operation. The drive to the box is by means of a shaft at the front of the machine, which is started and stopped by means of a large diameter expanding ring friction clutch, operated by a lever in front of it. With this device the long shaft at the front of the machine travels with the table, and runs at a constant speed. This large machine has a capacity of 36in. diam., and admits 16ft. between centres; another machine made by the same company, and nearing completion, has a capacity of 20ft. between centres. It carries a grinding wheel 40in. diam. and 3in. wide. One of the special features of this machine is the quick power motion for the wheel head, the movements of which are shown by an indicator directly in view of the operator. This is the first machine to have such a motion fitted, and being a frictional device is safe in operation, only a light pressure of the hand lever being required to set it in motion, while release causes it to be automatically disengaged.

The vertical surface grinding machine is another tool that has opened up a new field of usefulness. This type of grinding machine possesses advantages on certain classes of work, and will give a greater production than either milling, planing, or other methods of grinding. The grinding wheel employed is in the form of a ring or cup wheel, either continuous or segmental.

The work to be ground is carried on a table which passes to and fro under the grinding wheel, the method of operation being to bring the grinding wheel into contact with the work, and feed it toward the work automatically at each stroke of the reciprocating table. By this method, work can be ground at one setting up to practically the full diameter of the grinding wheel, and of a length governed only by the length of the table travel.

The Churchill machine, shown in Fig. 7, is designed on the unit system of construction—the body, upright, driving bracket, wheel head, spindle driving bracket, change speed gear box, and feed control apron all being built as separate units to simplify construction and assembling of the parts. All shafts run on ball journal bearings, and it might be here pointed out that Messrs. Churchill were the first grinding machine makers to introduce this system of bearings on their vertical machines. Another special feature is the balancing of the spindle. This is arranged so that the spindle is pulled away from the work. This prevents any tendency to lost motion, and ensures perfect solidity of cut.

The wheel head is carried on square gibbed slides of great length on the upright, and has an automatic down-feed with trip motion, which ranges from ·000125in. to ·0015in. at each stroke of the table.

SPONTANEOUS COMBUSTION OF COAL IN MINES.

THE first report of the Departmental Committee appointed by the Secretary of State for the Home Department upon the Spontaneous Combustion of Coal in Mines states that during the last 20 years 177 persons have lost their lives through accidents caused by spontaneous combustion in coal mines in the United Kingdom. The greatest danger from spontaneous combustion occurs in mines which generate large quantities of firedamp. Fortunately mines characterised by both of those features—generation of firedamp and liability to spontaneous combustion—are not so numerous as those in which only one or other exists. Thus, although the number of "gassy" (usually described as "fiery") mines is very large, only in two districts are such mines liable to spontaneous combustion to any considerable degree, viz., in North Staffordshire and York

shire. On the other hand, although the majority of the mines in South Staffordshire and East Worcestershire are liable to spontaneous combustion, few of them can be termed gassy; in fact, so comparatively free from gas are they that many of them are worked with naked lights. The fact that mines are now being worked to much greater depths than in the past, and the certainty that still deeper mining will obtain in the future, with consequent higher initial natural temperature and probable higher ventilating pressure, make it extremely doubtful whether the comparatively favourable conditions hitherto prevailing will continue. These observations apply to all districts.

The Committee find that a state of doubt exists as to what constitutes an underground fire, and consequently at what stage of the spontaneous heating notification should be sent to the Inspector of Mines. Cases frequently occur when it is impossible for the management of a colliery to say definitely whether a fire is or is not in existence. Gob stink may travel some distance from an inaccessible point in the gob or goaf and be detected in an airway or on the edge of the goaf, and a fire may or may not result. Fires have occurred, and only years afterwards has the fact been discovered, *e.g.*, when driving through an old goaf. The normal temperature of mines varies so widely as between colliery and colliery that it would not alone be a safe guide to give any fixed point on the thermometric scale which would constitute a standard for abnormal heating. The Committee think therefore that abnormal heating should be defined as a rise of a certain number of degrees above the normal temperature of the air in the main return airway of the seam being worked at the point of discharge into the upcast shaft. They are of opinion that notification should be sent to the Inspector of Mines: (1) When gob stink, smoke, or any other sign of combustion is observed. (2) When the temperature of the air in any accessible part of a mine is 20° Fah. above the normal temperature, or where the temperature at such place attains to 110° Fah. (3) When any flash has been observed coming from any pack or waste. They further recommend that as soon as any work is commenced for the purpose of discovering or combating a fire or anticipated fire, the Inspector should be notified of the fact.

Some doubt has existed as to whether the occurrence of a fire underground, even in a gassy mine, constitutes a dangerous state, seeing that the danger cannot be said to have actually arisen in the workings, though it may arise at any moment. Some mining engineers maintain that on the occurrence of a fire a place in a mine is not dangerous unless inflammable gas is actually present in dangerous quantity, the possibility, or likelihood even, of such an occurrence not constituting such a state as to render compulsory the withdrawal of persons. In most cases it is necessary that when once abnormal heating has been discovered in a mine, some persons should be employed at or near the seat of the heating, to prevent, if possible, it reaching a state of incandescence, or to combat the fire once it has occurred.

Having carefully weighed all the evidence submitted to them, the Committee are of opinion that: In mines in which safety lamps are used, whether in pursuance of the Act or of any regulation or order under the Act, or in mines in which ¼ per cent. of inflammable gas has been found in the return airway of any ventilating district of the mine on any one occasion: (*a*) When smoke or other signs indicative of a fire occur in any such mine the whole of the workmen should be withdrawn from the ventilating district affected, and before they are readmitted the manager and two representatives of the workmen (if the workmen elect to appoint two such representatives) should make an inspection, the result of which should be entered in a book to be kept at the mine for the purpose, and should be signed by the parties making the inspection. The men should not be readmitted to that part of the mine unless such report (jointly if the men's representatives take part in such inspection) states that it is safe to do so. (*b*) When the presence of fire has been definitely determined, that is to say, when actual fire has been located or is known to exist, the whole of the men working in the seam in which the fire has occurred, and in other seams worked from the same level, should be withdrawn from the mine, except those engaged in combating the fire, unless the seam is naturally wet throughout, or unless such other districts in the seam or seams worked from the same level are naturally wet throughout, or are adequately protected by some means which in the opinion of the Secretary of State is effective in stopping the progress of an explosion of coal dust. (*c*) In the event of a fire being dammed off the whole of the men should be withdrawn from the mine until the work is completed, and should not be readmitted until an inspection has been made in the manner recommended above, and the conditions reported safe.

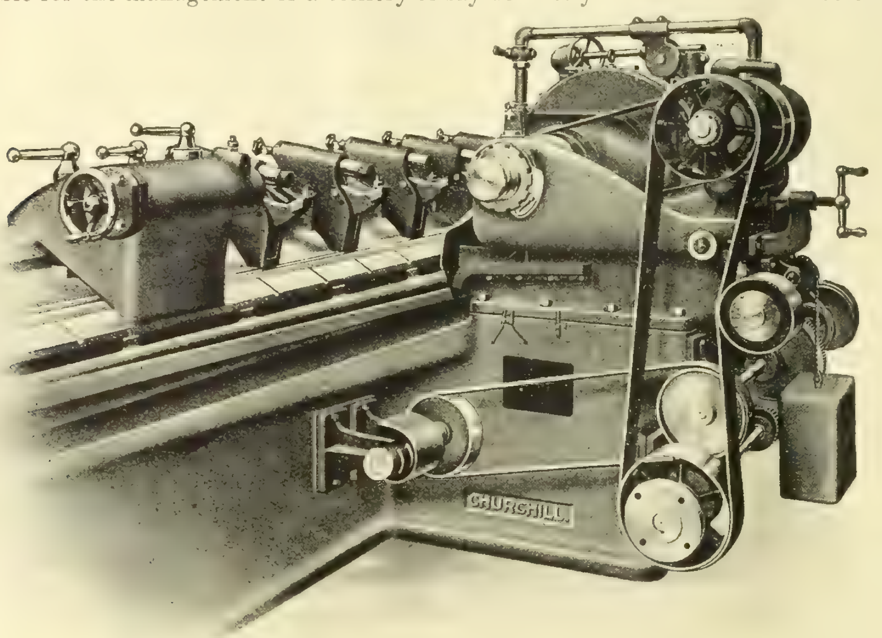


FIG. 6 —END VIEW, SHOWING METHOD OF SELF-CONTAINED DRIVE. (See page 143.)

ECONOMY OF POWER IN IRONWORKS.

A PAPER on this subject was recently read at Dudley Institute, by Mr. Frank Anslow, before the members of the Staffordshire Iron and Steel Institute. He remarked that during the last 21 years there had been extraordinary progress of improvements in the manufacture of pig iron and steel, in striking contrast to the complete absence of any notable improvement in the production of puddled iron. The generally accepted cause of this was that capital was difficult to obtain for investment in what appeared to be a decadent industry, but now that the position, if not actually assured, was, at least, more attractive, and after a prosperous period, it was perhaps not unreasonable to anticipate that money would be available for developments and improvements. The advent of a mechanical puddling furnace, capable of performing all the duties expected from it, would materially assist in restoring the industry to its old-time prosperity. There might be other developments, such as gas-fired puddling furnaces, forced draught, &c., in connection with the actual puddling process, but whatever they might be, and whatever direction they might take, the importance of economy in producing and utilising the power required for rolling and converting the puddled iron into finished material would not be lessened. Upon the question of power required, attention might be drawn to the growing tendency of iron makers to add steel-rolling plants to their works. Figures had been produced showing that in steel making, rolling, and finishing, the actual fuel cost for rolling and finishing,

excluding reheating, was only 5½ per cent. of the total cost of production. If a similar tabulation of costs for puddling and finished iron was available possibly a similar state of affairs might be revealed, but, even so, this comparatively small percentage represented many hundreds, even thousands of pounds per annum, which gave ample scope for economies. The methods at present available for securing additional

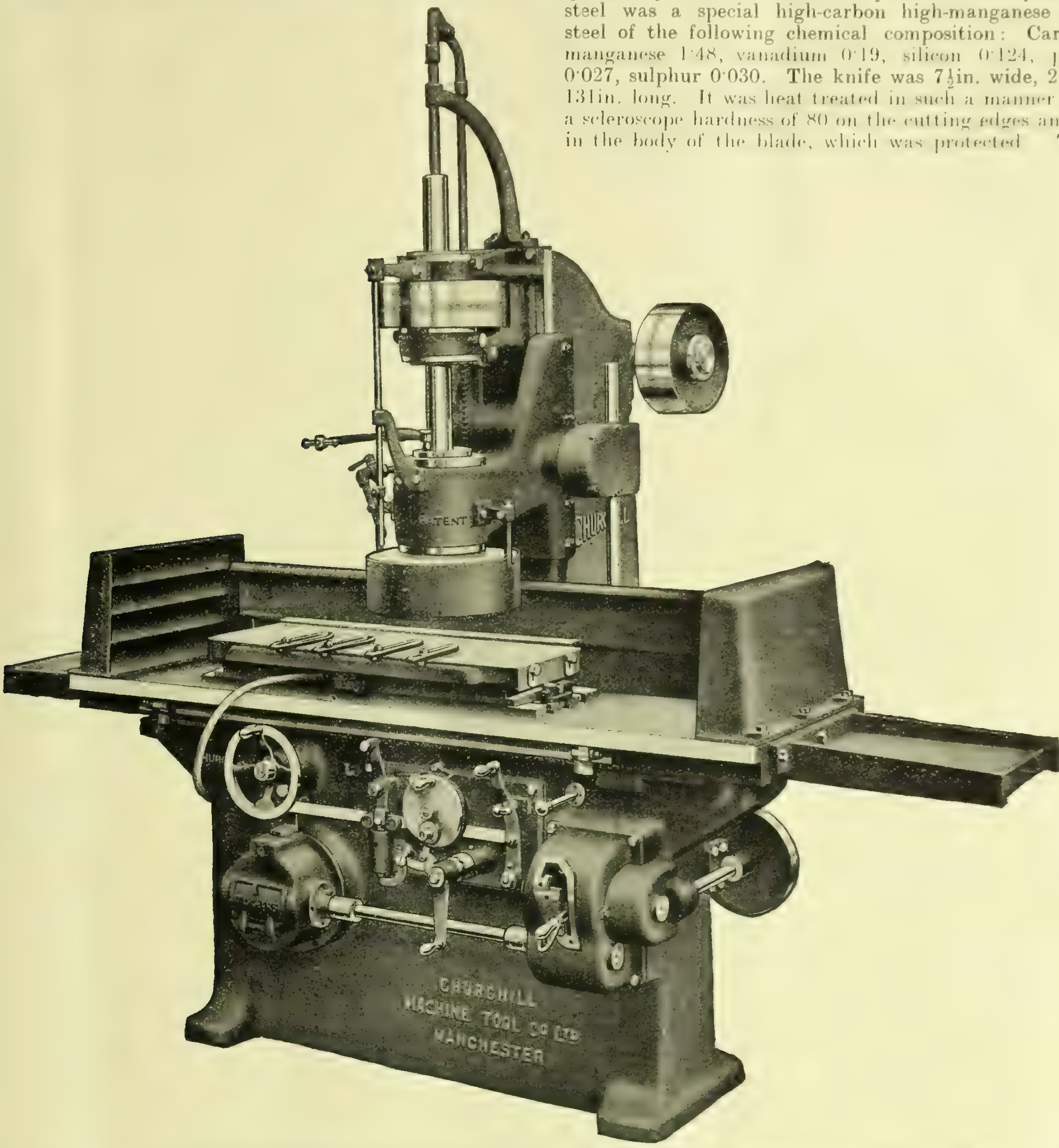


Fig. 7.—Vertical Surface Grinding Machine. (Note the centralised control of operating handles.) (See page 143.)

power or utilising to better advantage the existing steam supply were varied, but might be summarised under the following main heads: (1) Use of the live steam in new and economical engines with condensing plant. (2) Use of the live and exhaust steam in turbines for driving the mills direct through gearing. (3) Use of the live and exhaust steam in turbines for generating electric power and driving mills by means of electric motors. (4) Augmentation of existing powers by means of electricity.

The Iron and Steel Institute.—The annual meeting will be held at the Institution of Civil Engineers, Great George Street, Westminster, on Thursday and Friday, May 7th and 8th. The Bessemer gold medal will be awarded to Mr. Edward Riley, F.C.S. The autumn meeting will be held at Paris, on September 18th to 23rd, 1914, by the kind invitation of the Comité des Forges de France.

TESTS OF MANGANESE VANADIUM STEEL.

Service tests of a shear knife made of a new type of vanadium steel were, according to "The Iron Age," recently made by the Carnegie Steel Company, Pittsburg, in which the results obtained are so remarkable as to indicate that the steel in question promises to be an important development. This steel was a special high-carbon high-manganese vanadium steel of the following chemical composition: Carbon 0·72, manganese 1·48, vanadium 0·19, silicon 0·124, phosphorus 0·027, sulphur 0·030. The knife was 7½in. wide, 2⅝in. thick, 131in. long. It was heat treated in such a manner as to give a scleroscope hardness of 80 on the cutting edges and 50 to 55 in the body of the blade, which was protected. The knife was installed as the bottom blade in shears, in the armour-plate department, at the Homestead Works of the Carnegie Steel Company on November 14th, 1913. It remained in continuous service, with only one of the four edges of the blade being used, until December 16th, when it was taken out on account of fracture. During this time it cut 800 tons of scrap. Owing to the numerous cuts made in shearing scrap, a blade in this service is considered as doing 300 per cent. more work for a given number of tons cut than when doing ordinary shearing. In comparison, the average life of a blade, where all four edges are used, is 15 days when doing ordinary shearing, during which time it cuts about 150 tons of material. This gives an average of about 37½ tons per cutting edge, as compared with 800 tons, the record of the high-manganese vanadium steel blade. This latter service is the highest on record in the armour-plate department of the Homestead Works.

POWER PRODUCTION IN THE UNITED KINGDOM.*

BY EDWARD G. HILLER., M.I.C.E., M.I.M.E.

(Concluded from page 119.)

FIG. 6 has been drawn to illustrate approximately the changes of type of the principal types of engines in use for a period of years. The figure is intended to show the type or types of engine which were being adopted in new installations at the different periods indicated. The general form of each type of engine referred to is shown at the head of each column, and the width of the space shaded beneath is intended to represent the increase in the adoption of the type by the diverging line and the decrease in the adoption of the type by the converging line. It will be seen that the figure indicates broadly that while some of the types referred to have disappeared or become obsolete, there still remain at the present time a greater number of types available than was the case in earlier years. This is in accordance with experience—which shows that new types of prime movers do not render the old and existing types immediately obsolete but rather tend to form an additional useful alternative arrangement of power producer.

At the earliest period referred to on Fig. 6 (1850) beam engines driving by toothed gearing were a leading standard type for motive power in factories. This form of engine was the lineal descendant of the engines of Newcomen and James Watt. On the figure, a compound beam engine is shown, but of course, in the earlier days the beam engine was a single-cylinder condensing engine, compounding on the McNaught principle or other design being introduced later both for the alteration of old engines and in the construction of new ones. In the later periods of the beam engine, driving by toothed gearing and provided with wrought beams, a high degree of efficiency and construction was reached.

The small horizontal engine shown on the figure is, of course, a prototype of all the horizontal steam engines—which is the commonest type of steam engine in use in the country. The horizontal compound engine has gradually supplanted the beam engine for the purposes of general driving of textile and similar factories. The horizontal engine of the compound or triple-expansion type in its best form obtains a high degree of economy when combined with feed-water heaters of the economiser class and superheaters. One great virtue of the horizontal type lies in its accessibility, and this advantage has more than compensated for the disadvantage of the large space occupied by engines of this character. This class of engine remains to-day the standard type of engine for the driving of textile factories and the development of similar industrial power. The same general class of engine was also adopted to a large extent in the early days of electric power stations, but it has been displaced by steam turbines for the development of large powers.

The Willans central valve high-speed engine is referred to because it has a history of special interest. It was introduced as a single-acting high-speed engine, and was at that time the best practicable high-speed engine available. At that time, electric light stations were being equipped, and these being generally on the small scale in the first instance, this type of engine was adapted very well for driving dynamos direct on the shaft, and was adopted for this purpose in many stations. In a few years, however, the high-speed double-acting engine of the Bellis type combined with forced lubrication was introduced, and this appears to have gradually become the predominant type of high-speed reciprocating engine. This latter type continues in use up to the present day for moderate powers up to say 1,000 h.p.

The development of the steam turbine, indicated in column (*f*), is the outstanding feature of modern power engineering on the large scale. The steam turbine has become the standard type of prime mover for the development of large powers at electric power stations, but has so far not established itself effectively for the driving of individual factories.

Small gas engines have attained a very great development in this country for the production of powers in factories and works requiring, say, up to 50 or 100 i.h.p. In the early days of their development they replaced a number of small boilers and steam engines which previously were used for the development of small powers. The high power low-speed gas engine of the tandem type, which has a large use on the continent of Europe, is represented only by a limited number in this country. The present tendency in the design of large power gas engines in this country is in the direction of high-speed multi-cylinder engines. Many of these designs are still in the experimental stage, and the large gas engine for the development of power for industrial purposes is not yet in a satisfactory condition as regards design in this country, and has not attained any fixity of form.

Diesel engines are now one of the standard forms of power producers available, and are particularly suitable for certain circumstances. The total power in this class is not yet large.

Table II. shows the approximate fuel costs of different leading forms of engines in use. It has been compiled in order to show generally the qualities of representative modern engines of the classes referred to in the foregoing remarks, so far as fuel cost per indicated horse-power are concerned. Table III. gives reliability statistics of these different forms of prime movers. These reliability statistics are derived from the experience of the National Boiler and General Insurance Company, Ltd. They represent experience on this particular characteristic up to date. They, of course, are not permanent figures; the reliability of different types may be altered or improved by changes in the character of the maintenance, by increased care in driving, by improved construction, material or design. Any type, therefore, may progress from a low degree of reliability to a high degree, as indeed has been the experience in the past. Column N in Table III. represents the relative number of breakdowns of engines of that particular class per annum, the figures of steam engines being taken as 1. It is to be recognised, however, that the importance of breakdowns or stoppages is to be measured not only by the number, but also by the cost in making good. Column R has been added to represent the relative figures in this respect, steam engines being reckoned as 1. A broad survey of these figures indicates that steam engines, in respect of reliability, stand at the head of prime movers for comparatively large powers. The small gas engines up to 14in. diam. show even better results than steam engines of all sizes, but the larger gas engines, on the other hand, by their higher figures of the number of breakdowns and cost, show a substantially lower degree of reliability. The figures relating to steam engines and gas engines generally refer to comparatively large

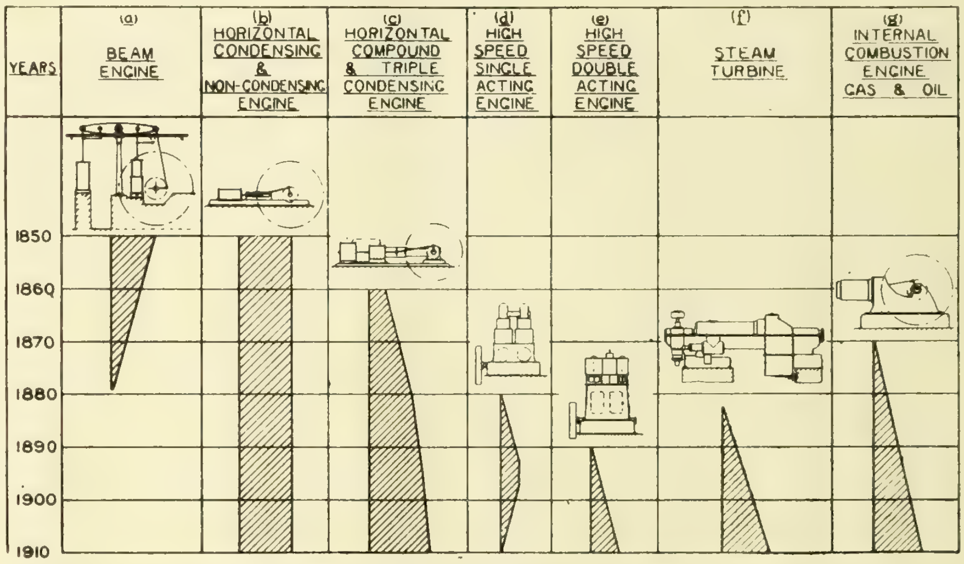


FIG. 6.—ILLUSTRATING THE ALTERATION OF TYPES OF NEW ENGINES INSTALLED FOR POWER PRODUCTION ON LAND IN THE UNITED KINGDOM.

* Paper read before the Manchester Association of Engineers, January 24th, 1914.

TABLE II.—*Approximate Fuel Costs of different Prime Movers.*

STEAM ENGINE, BOILER, SUPERHEATER.

Size I.H.P.	Steam Consumption, lbs. per I.H.P. hour.	Fuel Costs in Pence. Per I.H.P. hour.	Per B.H.P. hour.	Remarks.
250	13·3	·123	·137	Evaporation 7½lbs. water per lb. coal. Coal 13s. per ton. The steam figures are those actually obtained on test.
1,000	11·97	·111	·123	The mechanical efficiency of the engine is assumed to be 90%.

STEAM TURBINE, BOILER, SUPERHEATER.

Size.	Steam Consumption lbs. per KW. hour.	Fuel Costs in Pence. Per KW. hour.	Per B.H.P. hour.	Remarks.
1,000 I.H.P. Say 670 Kw.	15·1	·140	·111	Evaporation and price of coal as before. Steam consumption figures are obtained from Paper by Baumann given before Inst. E.E., in January, 1912. Efficiency of generator assumed to be 94%.
2,000 I.H.P. Say 1,350 Kw.	13·85	·129	·102	
5,000 I.H.P. Say 3,500 Kw.	13·6	·126	·100	

GAS ENGINES.

Type.	Fuel Consumption per B.H.P. hour.	Fuel Costs in Pence. per B.H.P. hour.	Remarks.
Town's Gas (600) B.T.U. Calorific value.	14·9 cu. ft.	·313	Cost of gas 1s. 9d. per 1,000 cu. ft. (Manchester Corporation). The quoted figures apply to Engines of about 50 B.H.P.
Suction Gas (Anthracite).	1lb.	·193	Anthracite 36s. per ton.
Bituminous Producer.	1·3lb.	·084	Slack coal, 12s. per ton. Fuel included stand-by losses.

DIESEL ENGINES.

Size.	Fuel Consumption lb. per B.H.P. hour.	Fuel Costs in Pence Per B.H.P. hour.	Remarks.
120 B.H.P. upwards.	·44	·212	Oil £4. 10s. per ton. This price fluctuates considerably.

numbers. Steam turbines and Diesel engine figures refer to small numbers. Of course, Diesel engines are not yet largely in use nor have they been sufficiently long in industrial operation to give an experience extending over a long period of years.

Reciprocating steam engines, of course, vary much in type, and the figures given in Tables II. and III. are intended to give a general idea of the qualities of steam engines in respect of economy and reliability. If this question were looked at more closely in detail, it would have to be recognised that each type of engine varied both in economy and reliability. This is obvious from a consideration of the variety of forms in which steam engines of old and recent construction are in use at the present time. Some old beam engines working at comparative low pressures still continue in use, driving by toothed gearing. The economic results of these is probably moderate and the reliability figures below the best. Then again, horizontal non-condensing engines have a high degree as regards reliability and a low figure as regards economy. Vertical high-speed condensing engines with forced lubrication give good results both in economy and reliability. Probably the highest degree in both directions as regards land engines is reached by the standard factory engine for textile factories with rope driving, working compound at moderately high steam pressures, provided by steam from a Lancashire boiler equipped with superheater and economiser.

It is well recognised that the steam turbine in its various forms attains a high degree of economy as indicated on Table II., and for powers of 1,000 i.h.p. and upwards for the development of electricity on land, it is the standard type of prime mover. It is not yet largely in use for the purpose of driving individual factories. The steam turbines covered by the figures referred to in Table III., are mainly of the Parsons type and show a considerable number of accidents, namely, 3·36 times as many as occur to steam engines *pro rata*, and taking account of the number and cost, 6·3 times. Most of the accidents have been of the nature of stripping of blading, also in a number of cases, cracking of castings and the like. The long distance between the bearings of turbines of this class, small clearance of the tips of the blades, combined with differences of expansion due to the difference of temperature, would appear to be the conditions which tend to increase the number of accidents. Reliability would probably increase with a reduction in distance between the bearings and greater clearance between the moving parts, which features are to be found in many of the later designs. The high ratio of accidents is probably not a permanent feature of this class of prime movers. The causes of accident are not inherent in the design of all turbines and can be reduced, and a substantial improvement in this respect is to be expected as a result of modification of design and construction.

The economic results as measured by fuel cost of each of the types of gas engine included in Table II. are good, particularly those working in connection with bituminous producers. If the general adoption of a prime mover were determined simply from a consideration of fuel costs, there is no doubt that the larger gas engines would have been much more generally adopted for the production of large powers than has been the case. The figures for gas engines as regards reliability have been divided into two sections, one up to 14in. diam. and the other from 15in. to 24in. diam. of cylinder. The figures include various designs of engines, but the great majority of them were of the ordinary type used in the United Kingdom, namely, the horizontal Otto-cycle type, usually having high reciprocating speed, close fitting piston which acts as a crosshead; piston not water cooled. Other types also enter into the figures but the above type is predominant.

Large gas engines of the horizontal slow running type, of say 1,000 to 3,000 i.h.p., are not included in these figures, the

TABLE III.—*Reliability of different Types as indicated by*
N—Number of Breakdowns. R.—Number of breakdowns × cost of repair per breakdown. In each case steam engines taken as 1

	N. Number of Breakdowns. Steam Engines taken as 1.	R. Number of Breakdowns cost per Breakdown. Steam Engines taken as 1.
I. Steam Engines	1	1
II. Steam Turbines	3·36	6·3
III. Gas Engines up to 14in.	·6	·24
IV. Gas Engines, 15in. to 24in.	2·82	3·01
V. Diesel Engines	3	3·75

author not having any statistics relating to this class of engine. When large gas engines of this class were first introduced, breakdowns of them were frequent and the reliability was low, but in recent years it is claimed that the running difficulties have, to a great extent, been overcome, and that particularly with blastfurnace gas the large gas engine is a highly reliable prime mover. The capital costs of these large engines have been high, and to meet this objection there has been a tendency on the part of many English firms to adopt quick running, vertical engines for power up to 1,000 i.h.p., these vertical engines having single cylinders or tandem cylinders on each line. These engines can be provided for a given power at a much lower capital cost than a large slow running horizontal gas engine.

The reliability figures for the gas engines up to 14in. diam are highly satisfactory, but those for gas engines from 15in cylinder diameter to 24in. cylinder diameter show that from this point of view these gas engines fall considerably below the standard of the steam engine in respect of reliability, there being 2·82 times as many breakdowns; the breakdowns multiplied by the cost being three times as much as that of steam engines. Had the large gas engine in this country worked with producer gas reached the same degree of reliability as the steam engine, there is no doubt that it would have replaced the latter to a much greater degree than has actually been the case.

One reason for the low degree of reliability in the case of large horizontal gas engines of the ordinary type is to be found in the design of these engines, which is a reproduction on a larger scale of the design originally adopted for gas engines of a much smaller size. In gas engines of small size, say 8in. to 12in. diam., the piston serves not only as the piston but also as the crosshead and slide. This duplication of functions considerably cheapens the construction of the engine, as compared with what the cost would be if there were a crosshead and a slide separately, as in a horizontal steam engine. This arrangement has served quite satisfactorily with the smaller engines. When, however, adopted as at present in the large engines of British design, the duplication of function on the part of the piston is not so satisfactory. In order to avoid knocking of the piston, the clearance between the piston and the cylinder is very small, and consequently material overheating of the piston is liable to cause sticking—in which case the connecting rod bolts are liable to be wrenched off or other damage caused.

The failures of these large, quick running engines include many cases of breakage of connecting rod bolts where the connecting rod is of the marine type. It is interesting to note that while steam engine breakdowns can commonly be followed up so as to determine the cause, in these gas-engine breakdowns the origin of the accident is often left obscure. In the ordinary quick running, Otto-cycle gas engine, the only tensile stress on the bolts of the connecting rod in the ordinary way ought to be the tension caused by the acceleration of the piston on the return stroke. Considerations of this kind, however, would not account for the remarkably sudden smashes of connecting rod bolts which take place, and this on the whole would tend to indicate that many of these smashes are due to the piston momentarily seizing. When such a smash has taken place, the connecting rod may or may not be whirled round by the crank; in case of suitable conditions prevailing it may result in jamming and fracture of the pin, the bending or fracture of the shaft, and practically the wrecking of the engine. Evidently, improvements in these particular directions may be sought for along the lines of larger piston clearances, possibly combined with water cooling, external crosshead and better type of connecting rod, lower load rating and lower speed. Such alterations would involve a somewhat considerable change in design of this particular class of engine, and of course would increase the first cost of the engine for a particular power.

Breakdowns of the larger sizes of ordinary gas engines in this country frequently originate in the attempt made to run these machines for long periods, such as day and night running for one or more weeks without a stop. Under conditions of this kind parts of the engine are likely to get out of adjustment and thus lead to a smash. For instance, as is well known, the connecting rod bolt may become a little loose, and being allowed to go on working for several hours or days the looseness increases, throwing stress on the other bolt and finally resulting in the breakdown of one or other of them, or in the wrecking of the engine. Experience would appear to indicate that the ordinary, quick running gas engine has not yet reached such a position of reliability as to be able to run safely without attention for periods of seven days or more. The loading of the engine is a vital question as regards the reliability of all kinds of internal-combustion engines. Heavy loading tends to breakdown. With easy loading a much higher degree of reliability may be attained.

When this paper was written the fuel costs of the Diesel engine, as shown on Table II., were materially above those of other types of power referred to, with the exception of gas engines from town's gas. With a lower price of oil, however, the economic considerations from this point of view would be very different, and there is no doubt that this particular form of engine, being self-contained and requiring no gas producer, has low stand-by losses and is very convenient in many instances. It has not long been in use as a prime mover on land in this country, and the figures cover only a limited field, but the statistics available to the author would indicate that, as shown on Table III., the engines of this type have three times as many breakdowns as steam engines, and breakdowns multiplied by cost about 3·75 times as high as steam engines. The failures include such things as fractures of cylinders, cracking of cylinder heads, fractures of connecting rod bolts, fractures of crank shafts and the like. It has to be recognised that although the engine is a highly efficient thermo-dynamic machine, it is a machine of complexity and great delicacy, and requires a high degree of efficiency in supervision, driving, and maintenance. Any relaxation of attention greatly increases the risk of failure, also such conditions as bad water (leading to deposit in the cylinder heads and jackets) increase the liability to cracking of these parts, while the pistons—not being water cooled—are liable, under unfavourable conditions, to overheating and seizing, which may or may not be followed by a general smash.

As regards the multi-cylinder, vertical engines either of the Diesel oil engine type or gas engines of similar construction, it is to be observed that it is possible that one cylinder may be inclined to stop from seizure of the piston or sticking, but the other cylinders may continue to operate in a normal way, resulting in the crank shaft dragging the piston of the disabled cylinder round until either the engine pulls up or breaks down. On the whole, experience with Diesel engines has resulted in a wide appreciation of their advantages, but has also been accompanied by a realisation of greater relative possibilities in the way of breakdown and accident than are present in the running of the normal steam engine.

Mechanical breakdowns in moving engines and similar machines vary, of course, in their nature from the mere fracture of a very small part—such as an unimportant bolt—to a complete breakdown, involving in some cases the complete wrecking of the machine. Generally, the greater size of the engine means heavier moving parts which are more expensive to replace. Higher speed means increased stored energy in the moving machine or engine. Large engines have necessarily proportionately more stored energy which, in a case of serious breakdown, is generally dissipated in destroying and in breaking up the machine.

Broadly, it may be said that large clearances make for safety. In steam engines, for instance, small clearances in the cylinder may easily be fouled by loose parts or filled with water from the condenser or from other sources, leading to breakdown. In turbines, small clearances lead to fouling in the expansion of the blade ends, reacting again by the friction of the rubbing blades, overheating the blades causing them to expand still more, culminating in the fusion of some of the blade ends, breaking off one or two and stripping of a number of rows. In gas engines and the like, small clearances of the piston in the cylinder increase the liability to sticking of the piston, and such momentary sticking might be followed by breakage of the connecting rod bolt and wrecking of the engine. A similar sequence of operations also takes place in Diesel engines, and in all cases the restriction of the clearances, which may be in the interests of economy of fuel, would appear to be against reliability as regards freedom from breakdown.

In the design of steam engines for textile mill purposes, long experience and old traditions, together with the influence

of the insurance companies (possibly the latter being an important factor), have resulted in the adoption of a slow moving engine equipped with the necessary precautionary devices to reduce the risk of breakdown to the lowest possible point. In the ordinary way, therefore, an engine having a high degree of reliability is adopted. In internal-combustion engines, on the other hand, the traditions of the manufacture are not as well established as in the case of steam engines; the influence of the insurance companies on the design of the engine has been so far much less than in the case of steam engines, and it is possibly largely due to these factors that the figures given for the reliability of gas engines and other internal-combustion engines fall considerably below the standard attained by the regular steam engine. Gas engines, in this country, in fact, have been largely influenced in their design by commercial and selling considerations rather than by considerations affecting their reliability so far as freedom from breakdown is concerned. The general results of the selling considerations tend to the adoption of a high-speed machine, highly rated for its size, and free from expensive complications, such as water cooling.

The foregoing characteristics which have been outlined in reference to the principal prime movers at present in operation do not exhaust the factors which have to be taken into account in the choice of power for each individual case. The particulars given indicate the result of experience in the two general directions of economy of fuel and reliability of running. Economy of fuel may in one case be more important than in another, according to situation and facilities. Where fuel is very costly, it is, of course, worth while to adopt greater refinements in the way of economies in the power equipment than is the case where fuel is at a low price. The capital cost enters largely into the question, and mere economy in fuel may cost so much more in original capital outlay that the interest and depreciation on the capital will outweigh the savings of the fuel costs. The questions of reliability of continuous running, regularity of running, and the like also become of importance according to the nature of the case, and the decision as to the most suitable power for any particular installation must depend upon full consideration of the nature and effect of the whole of the factors.

REVERSING MOTOR DRIVES AND AUTOMATIC CONTROL FOR MACHINE TOOLS.*

BY GEORGE W. CRAVENS.

AMONG the many important changes in shop practice due to the widespread application of electric motors there is probably none of greater importance than those due to the application of automatic reversing motor drives to planers, shapers, slotters, &c. While the great saving in power and the increased production due to this practice is appreciated, it is doubtful if the true importance of it is fully realised. Usually, the saving in transmission losses is the only thing considered, and, even though this may be 50 or 60 per cent. of the total power required, it is often only a small part of the real saving. The principal gain is in the increased production and decreased cost. The most efficient tool is the one which will do the most work in a given time without straining either the tool or the work; do it accurately and at the lowest cost for power and maintenance, and with the least loss of time between cutting operations. With tools that perform their work with a rotary motion of either the cutting tool or the work, such as lathes, boring mills, and drills, it is possible to make the tool work 100 per cent. of the time it is running, but with tools that operate with a reciprocating motion of either the cutting tool or the work, such as planers, shapers, and slotters, a portion of the time is lost when returning between cutting strokes. So the relation of cutting stroke and return stroke has an important influence on the amount of work that may be done in a given time.

With the direct-coupled automatic reverse drive the cutting and returning speeds are controlled independently, so it is possible to make the ratio between return and cutting speeds anything that may be desired, up to the practical limit. The speeds commonly employed for planing range from 50ft. to 100ft. per minute for the return stroke and from 25ft. to 50ft. per minute for the cutting stroke, the speeds depending upon the nature of the work. From this it will be seen that the ratio between the return and cutting speeds will be 2 to 1, and motors giving this ratio are easily obtained. But if a ratio of 3 to 1 is obtained there will be a gain of 12·5 per cent. in time required to do a given amount of work, while with a ratio of 4 to 1 the gain will be 20 per cent. We find, however, that the latter is hard to obtain unless the planer is made heavy enough to stand this service, on account of the shock produced in accelerating and stopping the platen or table when the speed exceeds 100ft. per minute. In order to reduce the cutting time to a minimum it is necessary to maintain as high a cutting speed as possible without injury to the work or to the tool, so the nature of the work must be taken into account. If the piece is small or sets low on the platen the speeds of both cut and return may be greater than if the piece is heavy or sets high above the platen. The weight of the platen itself must also be taken into account.

The reason a direct-coupled reversing planer drive is so effective is that there is no power wasted in intermediate belts, pulleys, or shafts, and there is no slippage. Since the power necessary to operate a planer or any other tool is the sum of the power required to do the work and the power used to overcome the friction and other losses in the driving mechanism, it is evident that, for a given job, a comparison of the no-load powers will show the difference between any two systems of drives. We find by a large number of comparisons that the saving made by using direct-coupled motors averages over 40 per cent. With a direct-coupled motor using dynamic braking, the most common method, the current used on reversals is less than with the shifting belt method because enough must be taken from the line, in the latter case, to stop the planer in addition to that required to start it and run it. With dynamic braking it is only necessary to use energy enough to start and run the planer, the energy developed in stopping the planer being absorbed in the motor armature and the resistances.

The cost of maintenance, where belts are used, must include the labour and material for repairing and replacing belts; labour and material for pulley, countershaft, and bearing repairs; value of time lost while making repairs, if any; cost of general maintenance, oiling bearings, tightening belts, &c., and maintenance of motor and its controlling apparatus. When direct-coupled reversing motors are used the only item to consider is motor and control maintenance. No accurate general figures could be obtained as to the time lost in production due to the use of belts, because the labour necessary to repair and replace belts varies so in different shops, but we know the productiveness of the tools is increased when reversing motors are applied because there is no belt slippage; no flywheel effect or inertia of pulleys to overcome; the cutting speed is adjustable to suit materials and cuts; the return speed can be adjusted to suit the work; no belts or countershafts are to be repaired; and a large amount of time is saved when setting up the work because the platen may be moved any required amount at will.

We have also found that where direct-coupled automatic reversing variable-speed motors have been installed on planers formerly equipped with belt drive the increased production averages 33 per cent. This means that if a shop has three planers and is so busy as to require a fourth one, the floor space and operating expense of the fourth can be saved by equipping the three existing ones with automatic reversing motors and controllers. The cost of three such equipments of medium or large size, for corresponding planers, will be about one-half that of the fourth planer, thus adding to the sum saved by the change. The various makers have worked out variations in the details of their equipments, but all follow the same fundamentals: that is, the motor must accelerate, stop and start in the reverse direction, and the speed must be adjustable. The planer must also be protected in case of trouble on the power circuit, for if the voltage should go off while the machine is running the platen might run off the bed unless the motor stopped and held it. The essential parts of all control sys-

* Abstract of paper presented before the American Association of Railway Electrical Engineers.

tems are three in number—a contactor panel, a master switch, and a resistance.

If it is true that one of the most important advantages of motor drive is increased output, it is equally true that motor control is also important, for it is only through proper control that increased output can be obtained. So long as a motor is no more than a driving element it is but very little better than a belt from a line shaft, but when that motor is made to vary in its action as required it then becomes a really valuable adjunct to any machine tool. Nearly all of the power-consuming work done in machine shops consists in removing metals in the form of chips. That is, the output of any machine is generally measured in terms of the amount of metal it can remove in a given time. Hence, anything which will help a machine remove more metal in a day is a decided and very valuable improvement. It has been estimated that an increase of but 5 per cent. in the output of the average machine tool will increase the earnings enough to pay back the cost of applying the motor drive and control inside of two years. When the control of that machine is made as nearly automatic as possible, the gain is still greater.

A machine gives maximum output when worked at the highest economical speed and when operated on productive work the maximum amount of time. Plenty of power must be supplied to and at the cutting tool, and the speed must be variable over a wide range if the machine is to work at its highest economical speed at all times. Proper control and large motors are necessary to this end. It is along the line of adopting automatic control for machine-tool motors that a very large part of the advance in shop practice will proceed. Shunt-wound, adjustable-speed direct-current motors, or alternating-current motors of essentially those characteristics, are used for most machine tools, but they require suitable controlling apparatus before they are really satisfactory.

Automatic control of a motor provides the limiting of the starting, stopping, or reversing current to a predetermined value; starts, stops, or reverses the motor in the proper amount of time, protects the motor from grounds, short circuits, and commutator troubles, and limits the torque in the motor and in the machine it drives. Automatic control not only relieves the operator from the physical acts of starting, stopping, and reversing his motor, but also relieves him from the mental exertion necessary to the proper regulation of a motor by a hand controller. He will seldom turn the handle at just the right speed, whereas the automatic controller gives him the fastest safe control and leaves him entirely free in mind and body for his part of the work. In general, any system of automatic control, to be satisfactory, should provide for: (1) The motor must start from rest and attain the speed corresponding to the setting of the field rheostat in the shortest safe time and with the current held within safe limits; (2) the motor must be reversed in the same manner and with the same automatic protection; and (3) the motor should be stopped by dynamic braking or any other similar and suitable method. Preferably this should be accomplished by means of push-button control when required.

Automatic control has been satisfactorily applied to machines with heavy inertia loads, such as punch presses, shears, bulldozers, forging and upsetting machines and others with heavy flywheels for both starting and stopping them. In place of clutches for connecting and disconnecting the motor and machine, the automatic controller allows of starting the motor quickly and safely and stops it by means of dynamic braking in the minimum of time. This type of control has also been applied to shapers, slotters, and planers to good advantage.

Electric Traction on the Midland Lines.—The Directors of the Midland Railway Company have, we understand, decided to adopt electric traction on its lines from St. Pancras to Hendon. This company has already made a successful experiment with electrical working between Morecambe and Heysham. The company is also working the Burton and Ashby Light (Electric) Railway, and it is intended to electrify the London, Tilbury and Southend line, which was recently acquired by the Midland.

THE MEASUREMENT OF STRESSES IN MATERIALS AND STRUCTURES.*

BY PROF. E. G. COKER, M.A., D.SC.

(*Concluded from page 133.*)

It has already been noted that the thermal effect of stress in an elastic material is proportional to the sum of the principal stresses at a point, and it is possible that this may be of service for some cases where each principal stress is required, especially as it is directly applicable to metals as well as transparent bodies, but the corrections required are not small and the measurements are difficult. It is therefore more convenient, in general, to measure the sums of the principal stresses by observing the changes of thickness of the plate. It is easy to show, for a plate of elastic material subjected to stresses in its own plane, that the change of thickness is equal to the sum of the principal stresses across the section multiplied by certain easily determined physical constants. We have therefore a means of determining this sum, if we can measure these lateral changes with sufficient accuracy. A convenient form of extensometer† has been devised for this purpose capable of measuring changes of thickness of half-a-millionth of an inch in a plate ¼in. thick, and in this way the sum of the principal stresses can be

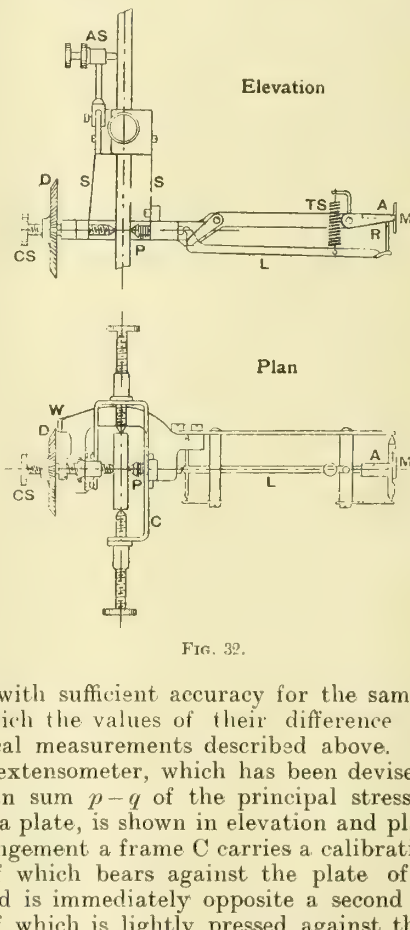


FIG. 32.

determined with sufficient accuracy for the same points of a plate for which the values of their difference are obtained by the optical measurements described above. One form of this lateral extensometer, which has been devised for obtaining the mean sum $p-q$ of the principal stresses across the thickness of a plate, is shown in elevation and plan in Fig. 32. In this arrangement a frame C carries a calibrating screw CS, the point of which bears against the plate of transparent material, and is immediately opposite a second point P, the inner end of which is lightly pressed against the plate by a spring, while the outer end presses against the short arm of a pivoted lever L controlling the angular position of the lever A of a pivoted mirror M. Any change which takes place in the thickness of the specimen between the measuring points causes a rotation of the mirror, and this change can be measured by observing the movement of a spot of light which is reflected from the mirror. The observations can be calibrated by the standard screw CS, which is provided with a graduated head L for this purpose.

It will be noticed that the measuring points simply bear against the face of the bar, and do not penetrate it, so that the length over which a measurement is made is not altered by the action of the measuring points penetrating the material. The whole of the measuring apparatus is, more-

* Cantor lectures delivered before the Royal Society of Arts, December, 1913, and reproduced from the Journal of the Society.

† "The Distribution of Stress due to a Rivet in a Plate," by E. G. Coker and W. A. Scoble, "Transactions," Inst. Architects. 1913.

over, supported on a pair of light steel springs S attached to a clip, secured to the specimen, so that errors caused by the weight of the instrument on the measuring points are also avoided. We have therefore at our disposal purely experimental means of determining the directions of principal stress at a point in a plate, and also the magnitudes of their sum and difference for the same point, when taken as averages over the thickness of a plate. This information is

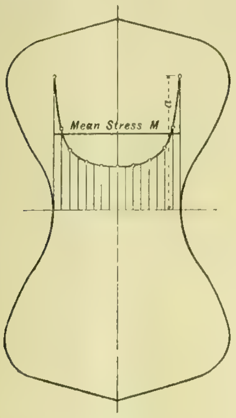


FIG. 33.

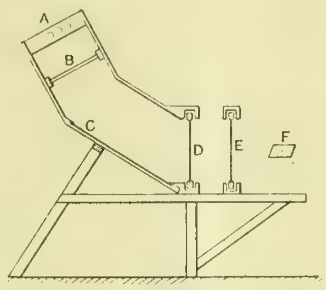


FIG. 34.

sufficient to determine the stress distribution completely. For optical investigations on models of engineering interest it is of importance to use a transparent substance which possesses marked doubly refracting properties under load, combined with ability to resist severe stresses without causing injury to its optical properties.

Glass is, in general, too fragile for this purpose, and the cost of making models of the required shapes is too great for it to be used with advantage. These difficulties are overcome by the use of one of the nitro-cellulose compounds now available. These materials approach glass in the perfection of their optical properties, and are very much superior in ductility, while the cost of fashioning the material into complicated shapes is only a small fraction of the cost of specimens made of glass.

An interesting problem of stress distribution, examined by the aid of xylonite models, occurs in the testing of the tensile properties of cements. As is well known, rules exist in most countries which prescribe the form of a cement tension member so that tests made on different samples of cements can be compared, but unfortunately there is no general agreement, and the standard briquettes of continental Europe, America, and England differ very appreciably in form, and have, in fact, no common basis for the comparison of the results of tests. If, for example, we take a model of a briquette of the standard form prescribed in British specifications for the testing of cement, and subject it to load, the stress distribution can be completely determined by the methods described. Experiment shows that the stresses acting perpendicularly across the minimum section of the briquette are accompanied by stresses in the plane of the section, which vanish at the outer end, and are probably never very great at any point. We may, for an approximate comparison, neglect this minor principal stress everywhere, and it is clearly zero at the outer edges of the section where the stress is most intense.

Fig. 33 shows the difference of the principal stresses at the cross-section of a model of a standard British cement briquette, and measurements* show that the maximum stresses occur at the ends of the cross-section, and are approximately $1\frac{3}{4}$ times the mean average value of the stress. Similar measurements show that the maximum stress for the American form is about 1·7 times the mean value, while for the continental form the ratio rises to as much as 1·95 to 1. It would no doubt be more satisfactory if the stresses could be actually determined in the cement itself, but this direct determination presents very great difficulties. A more accurate representation of the real state of stress in a cement briquette might possibly be obtained by using glass models, since the brittle nature of this material is more akin to that of cement than the ductile celluloid used here. It is, however, very probable that the elastic distribution in glass would not prove very different from that in celluloid, but would remain persistent up to fracture, so that the present results may not be very far from representing comparatively the stress distribution at the section examined. A general survey of the distribution of stress throughout the briquette has so far not been attempted, but the colour effects produced in a model showed the stress difference effects directly, and it was evident that there were also very severe stresses at sections in the neighbourhood of the grips. It is, in fact, not unusual for briquettes to fracture here instead of at the minimum section.

For the examination of models of engineering structures it is very convenient, and sometimes necessary, to view the whole of the model at one time, and the restricted view which can be obtained in the polariscopes obtainable from makers of optical instruments only allows very small models to be used. In order to remove this serious objection several large polariscopes have been designed and constructed, and cross-sectional views of two of these are shown (Figs. 34 and 35), of which the former has a field of view of about 1 sq. ft. and the latter 40in. by 10in., and especially adapted for long models of girders, roofs, and the like. The essential features are the same in both cases, and consist of a bank of lamps A, the light from which passes through diffusing screens of tissue paper B before reflection from a black glass surface C. The reflected and polarised beams then pass through a quarter-wave plate D of mica, whereby they become circularly polarised for passage through the object. The emergent rays are again changed to a plane-polarised state by the action of a second quarter-wave plate E, and finally pass through the analyser F, which may take the form of a Nicol's prism as in the first figure, or a bundle of clear glass plates, as in Fig. 35. Both these examples are very suitable for laboratory work, and other modifications have also been used which have been found more suitable for certain cases, but these latter involve no change of fundamental importance.

The complete experimental solution of the stress distribution in a body may be illustrated by the case of the action of a rivet near the edge of a plate of a rivet joint. In this problem we can no longer neglect either principal stress, and it is in general necessary to determine both their directions and magnitudes. If the uniform tension stress in the full section of a plate is represented by equally spaced lines in the direction of stress, we may expect to find alterations in their directions and distances apart as they draw near to the discontinuity produced by the rivet, and an optical examination (Fig. 36) shows that the lines of stress approach one another very closely as they pass around the

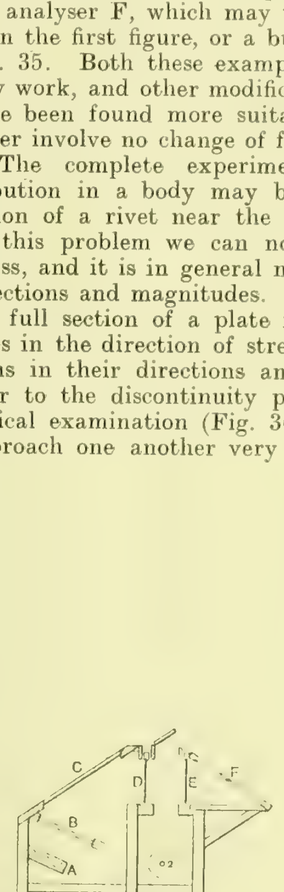


FIG. 35.

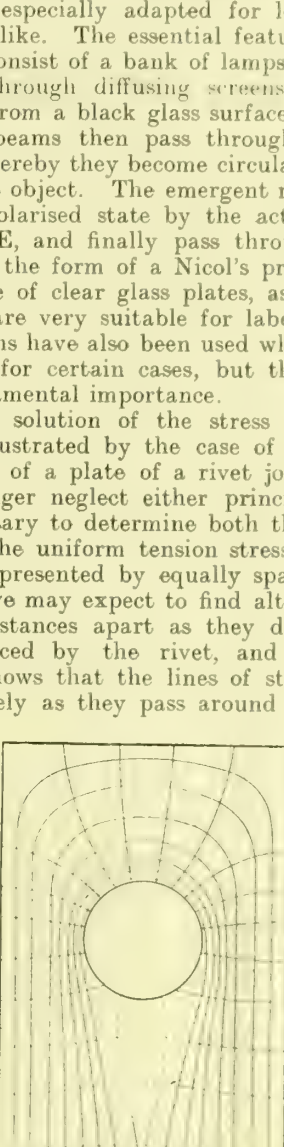


FIG. 36.

rivet and afterwards diverge again if the overlap of the plate is sufficient to permit this. It is not difficult to explore the whole of a plate stressed in this way, by determining both the sum and difference of the stresses at a sufficient number of points on the lines of stress so found, and some of the measurements for the cross-section passing through the centre of a rivet in a plate are shown in Table XII., for the case of a plate in which both the overlap and the widths of

* "The Distribution of Stress at the Minimum Section of a Cement Briquette," by E. G. Coker. International Association for Testing Materials. New York Congress, 1913.

metal on each side of the rivet are equal to the diameter of the rivet. In these determinations the distance r of the point examined is measured from the centre of the rivet in terms of its radius a, while the stress p_r across the section of the stress p_t in the section are given in terms of the mean stress.

The experimental values of the sums and differences are plotted in Fig. 37, and the principal stresses deduced from

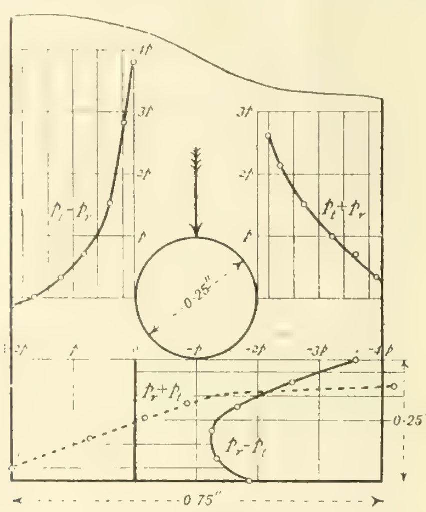


FIG. 37.

them are given in Fig 38. They show that the tensile stress at the cross-section reaches a high value, while below the rivet an even greater compression stress is produced. The measurements of radial stress along the sections chosen give marked compression close to the rivet, and it is worthy of note that they are very nearly zero at the outer boundaries of the plate, results which confirm the general accuracy of the measurements. Other measurements of a similar kind show that the action of a rivet produces an intense stress at the hole, sometimes reaching five times the stress in the full plate. In a transparent model this is often accompanied by permanent overstress and local yielding, which latter tend to equalise the stress in the material.

We have seen that the complete determination of the distribution of stress in a plate subjected to forces in its own plane involves the determination of the directions of the lines of stress, and the measurement of both the sum and the difference of the principal stresses at each point, since these latter cannot in general be measured separately. It is therefore apparent that this kind of investigation offers great advantages for the measurement of shear stress, since the optical effect is proportional to the difference of the principal stresses, and therefore varies according to the shear stress at

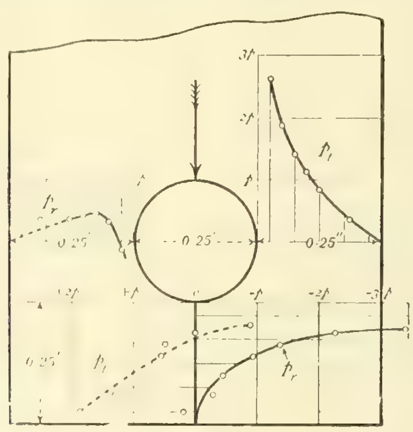


FIG. 38.

a point. The quantitative determination of shear stress is accordingly of a simple kind, since the delicate measurements of the change of thickness in a plate are not necessary, while a general idea of the distribution of shear stress may be obtained from the picture which the colour effects show.

The distribution of stress in a long rectangular plate subjected to shear stress offers a useful illustration, which may be considered in some detail. For the purposes of experiment a plate 10in. long and $\frac{3}{16}$in. thick was rigidly clamped at the sides B, Fig. 39, and a pull due to a load W was applied to a bar clamped to the centre of the plate, so that the free

TABLE XII.

STRESSES ACROSS THE SECTION.

$\frac{r}{a}$	1·20	1·40	1·60	1·80	2·00	2·50	3·00
$\frac{p_t+p_r}{p}$	2·55	2·20	1·84	1·47	1·18	0·70	0·22
$\frac{p_t-p_r}{p}$	2·80	1·60	1·00	0·76	0·56	0·10	−0·17
$\frac{p_t}{p}$	2·68	1·90	1·42	1·11	0·87	0·40	0·02
$\frac{p_r}{p}$	−0·125	0·30	0·42	0·35	0·31	0·30	0·195

STRESSES ON CENTRE LINE BELOW RIVET.

$\frac{r}{a}$	1·40	1·50	1·70	1·90	2·20	2·50	2·80
$\frac{p_r+p_t}{p}$	4·31	−2·32	−0·90	−0·37	0·43	1·27	2·05
$\frac{p_r-p_t}{p}$	−2·56	−2·32	1·87	−1·48	−1·25	−1·32	−1·60
$\frac{p_r}{p}$	−3·44	−2·32	−1·39	−0·93	−0·41	−0·025	0·225
$\frac{p_t}{p}$	−0·88	..	0·49	0·55	0·84	1·30	1·82

portions A on each side were subjected to a nearly pure shear. With the aid of a large polariscope the optical effects produced

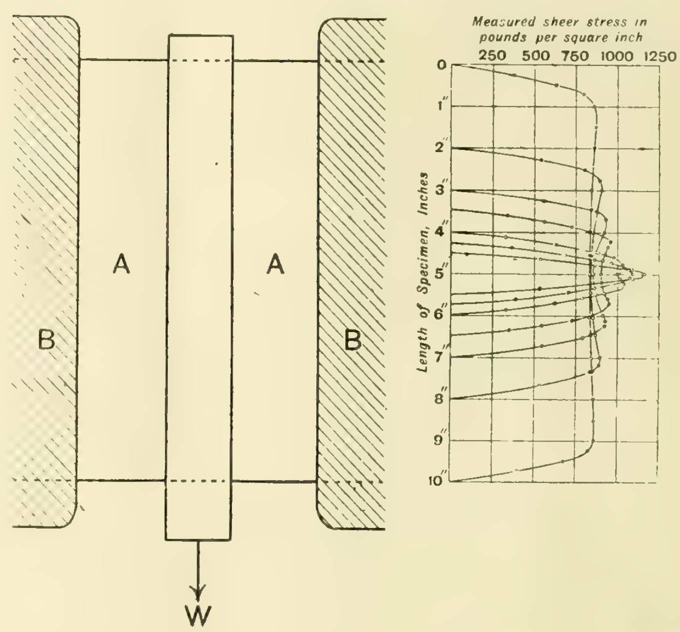


FIG. 39.

over the whole plate could be readily observed, and it was found that the distribution presented some interesting peculiarities. In a long plate the maximum intensity of stress occurs near the ends, and, in general, at a distance therefrom somewhat less than the free width of the plate. The stress is very uniform over the remaining part of the length, with a slight diminution towards the centre, as is shown in the accompanying diagram, for the maximum length of 10in. and a mean shear load of 800lbs. per square inch. The shear stress over the central portion of the 10in. length is slightly more than the mean shear load, and reaches maximum values at short distances from the ends, and it ultimately becomes zero at the ends.

Keeping the load per square inch constant and diminishing the length to 6in., we obtain a slightly more variable distribution over the central portion, with a higher average stress intensity and more pronounced maxima. The same general features are shown in a still more marked manner as the length is still further decreased, and a change of distribution is seen to be imminent when a length of 2in. is reached, for we observe from the measurements that for some length greater than $1\frac{1}{2}$in. and less than 2in., the distribution changes to one with a central maximum, and approximates to a parabolic type with a very large maximum value, as the final curve shows.

Another field of usefulness for optical observations which may be indicated is their application to the design of structural members and parts of machines by aid of models subjected to load. We have seen from our tests that signs of failure are accompanied by a loss of transparency of the material, which is very readily observable and marks the places of high stress intensity in the member where failure may probably occur. It is therefore easy to correct errors in design from such observations, and these latter appear to be quite as useful, and are certainly more readily obtainable than from tests upon members of full size. Many other illustrations might be given of the effects of stress upon transparent materials, but those already described are perhaps sufficient to show the use of optical methods for determining the distribution of stress in models of engineering and like structures.

RELIEVING AXIAL THRUST IN STEAM TURBINE SHAFTS.

In the construction of steam turbines of the axial or parallel flow type it is usually found necessary to make the portion of the rotor of much larger diameter than the glands on the rotor shaft where the latter passes through the turbine casing. The axial thrust on the turbine shaft arises from the fluid pressure acting upon the annular area between the diameters, and as this area is large even a low fluid pressure produces a considerable axial thrust. Similarly, an axial thrust is produced on the shafts of turbo-blowers, compressors, and rotary pumps, and various means have been proposed to balance such thrusts. In marine turbine installations part of this axial thrust can be balanced by the thrust of the pro-

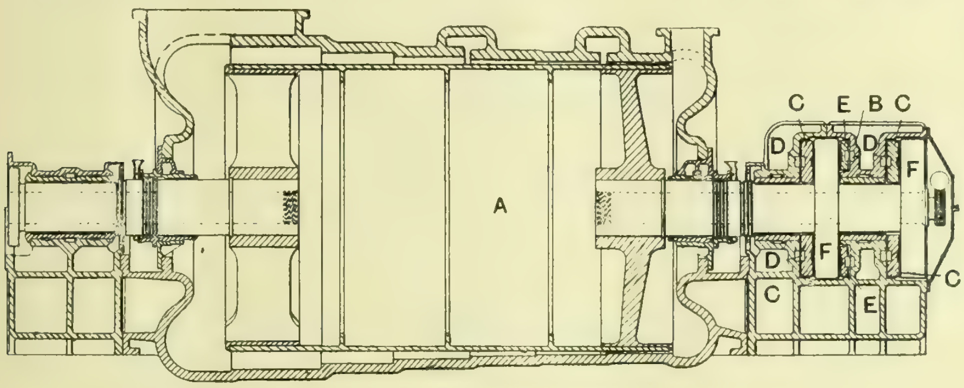


Fig. 1.—Arrangement for Relieving Axial Thrust in Turbine Shafts.

peller, but such propeller thrust in almost all cases represents only a very small proportion of the steam thrust. In the most usual arrangement the turbine is constructed for unidirectional flow, and balance pistons, which are virtually glands of large diameter, are employed. These pistons are usually placed at the inlet of the turbine and subjected on one side to a greater fluid pressure than on the other side, so as to create an opposing axial thrust in the required direction. In order to reduce the leakage from the high to the low-pressure side of these pistons it is necessary to provide these with labyrinth rings or with carbon, metallic, or other packing. In the former case, however, considerable leakage occurs, while the latter gives rise to a large friction loss, and in both cases the lengths, weight, and cost of the turbine installation is increased.

In order to overcome the above-mentioned disadvantages it has been proposed to take the entire axial thrust of a steam turbine upon a thrust block comprising a number of pressure plates whereby the oil film is automatically maintained by the difference of pressure existing at different points and the drag exerted on the oil by the moving parts. It has been found by experiment that thrust blocks having one of the contact surfaces formed by pivoted pressure plates are capable of absorbing thrusts exceeding 1,500lbs. per square inch of working surface with a frictional loss which is for all practical purposes negligible, and without appreciable wear, while with the hitherto usual type of thrust block greater pressures than from 20lbs. to 30lbs. per square inch of working surface have not been permissible under the best conditions of lubrication. Even with these low pressures in the usual type of thrust block the frictional losses are considerable, and the wear of the collar surfaces necessitates frequent readjustment to preserve the rotor of the turbine in its correct position.

The accompanying illustrations show arrangements of turbine and compressor installations in which the axial thrust is sustained by a thrust bearing in which the oil film is

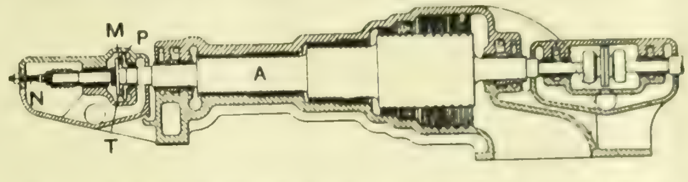


Fig. 2. Arrangement for Relieving Axial Thrust in Turbine Shaft.

automatically maintained. In these arrangements, which have been patented by Messrs. C. A. Parsons & Co., Turbinia Works, Newcastle-on-Tyne, the axial thrust on the shaft is absorbed mainly or entirely by a thrust block of the pivoted pressure plate type in which the pressure plates are symmetrically supported. With these arrangements it is not necessary to balance the axial thrust on the turbine or compressor shaft, although if desired such thrust may be so balanced to a small degree. The improvements also include a turbine installation in which the direction of flow of the working fluid through the turbine is reversed so as to neutralise under normal conditions the axial thrust on the turbine shaft, and in which a thrust block of the pivoted pressure plate type having symmetrically-supported pressure plates is provided to absorb the large end thrust arising when the normal distribution of pressure throughout the turbine varies.

Referring to the illustrations, Fig. 1 is a longitudinal section through a reaction marine turbine in which universally pivoted symmetrically supported pressure plates are employed. Fig. 2 is a longitudinal section through a reaction turbine suitable for land purposes. Fig. 3 is a longitudinal section to an enlarged scale showing the arrangement of thrust bearing in the turbine illustrated in Fig. 2, and showing the adaptation of pressure plates symmetrically pivoted about an axis lying in a plane at right angles to the direction of relative motion between the pressure bearing surfaces. Fig. 4 is a longitudinal section of a part of a blower.

In the arrangement shown in Fig. 1, the whole of the axial thrust arising from the steam pressure on the turbine rotor A, which thrust may be increased or diminished by the propeller thrust or by reversals of flow, is absorbed by a thrust block B of the type before referred to. In some cases, however, the turbine may be provided with means for balancing, apart from the thrust block B, a portion of the axial thrust. In any case, however, the greater portion of this thrust is carried by the thrust block. The pressure plates C and E of the thrust blocks are pivoted about an axis lying in a plane at right angles to the direction of relative motion between the bearing parts and bisecting the contacting surface of the pressure member, that is, the plates are symmetrically supported about the bisecting axis, or such plates may be pivoted upon a curved pad D so as to be capable of movement about any axis passing through their point of support, the point of support being at the centre of figure of the bearing surface of the pressure members. The thrust bearing takes the form of two collars F upon the rotor shaft against the aft faces of which the pivoted pressure plates C bear. A smaller set of pivoted plates E bears against the forward face of one of the collars F in order to determine the position of the rotor and to take any ahead thrust not balanced by the steam thrust. In this turbine installation no balancing pistons are required, or such pistons can be made of small dimensions or the pressure across them materially reduced. The loss in energy of working fluid by leakage or friction is also either avoided or considerably decreased, so that an improved efficiency of the turbine is

obtained. Also the thrust blocks are of short length, and with the simplified construction of the turbine now rendered possible an appreciable reduction in the weight of the turbine and in the total length of the installation can be effected.

The arrangement shown in Fig. 2 is applicable to land turbines. In this case the thrust bearing is placed at the high-pressure end, a set of pivoted pressure plates M bearing on a spherically seated member P being provided to take the thrust due to the steam pressure, while an adjustable bolt N

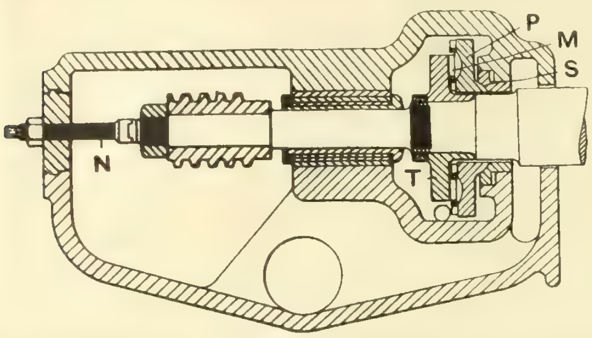


FIG. 3. ARRANGEMENT FOR RELIEVING AXIAL THRUST IN TURBINE SHAFTS.

bearing on the end of the shaft is provided to exactly determine the longitudinal position of the rotor. The thrust block may be placed at the exhaust end of the turbine instead of at the inlet end, and the collars T may conveniently be made separate from the shaft and secured by nuts against a shoulder, as shown in Fig. 3. This latter illustration shows in detail one form of pivoted pressure plate thrust bearing in which the plates M faced with bearing metal are pivoted

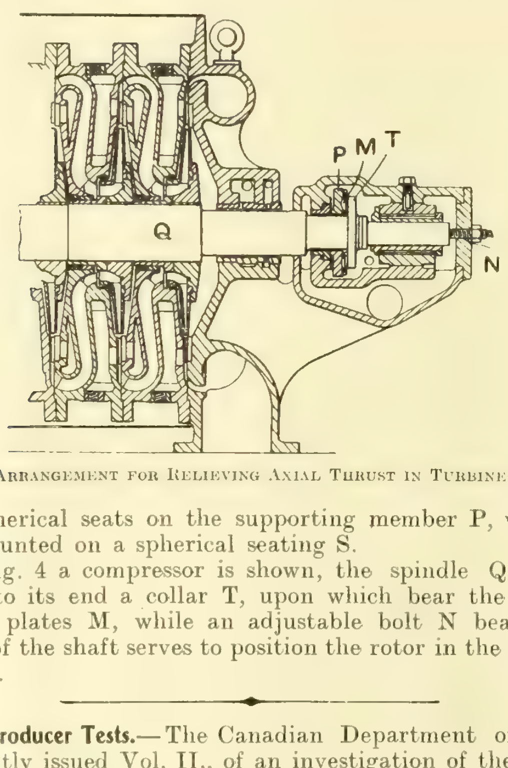


FIG. 4.—ARRANGEMENT FOR RELIEVING AXIAL THRUST IN TURBINE SHAFTS.

upon spherical seats on the supporting member P, which is itself mounted on a spherical seating S.

In Fig. 4 a compressor is shown, the spindle Q having secured to its end a collar T, upon which bear the pivoted pressure plates M, while an adjustable bolt N bearing on the end of the shaft serves to position the rotor in the opposite direction.

Gas Producer Tests.—The Canadian Department of Mines has recently issued Vol. II., of an investigation of the coal of Canada, in which the subject of gas-producer tests is dealt with by Mr. R. J. Durley. The main objects of a gas-producer test, for whatever purpose it is made, must, he mentions, be to measure or determine: (1) The amount and calorific value of the fuel consumed by the producer in a given time. (2) The amount of the heat value of this fuel actually utilised and available in the gas supplied during the test interval to an engine or furnace. (3) The amounts or items by which the loss or difference between (1) and (2) can be accounted for. (4) The suitability of the gas for its intended use, and the reliability and freedom from trouble of the producer when in service with the fuel to be employed. Mr. Durley explains that the first difficulty occurring is that of determining the coal consumption. If at the end of a run, one could be certain that the condition of the fuel bed was exactly the same as at the commencement, this difficulty would disappear.

ALCOHOL AS A MOTOR FUEL.

AT a meeting of the Royal Society of Arts held in London on the 4th inst., a paper on "Motor Fuels, with special reference to Alcohol" was read by Mr. W. R. Ormandy, D.Sc., F.C.S. In dealing with a new fuel there are, the author said, two questions of equal importance: Can it be used, and can it be produced cheaply enough and in sufficient quantities? That alcohol can be applied with perfect success in specially-designed engines has been more than sufficiently proved in Germany, where thousands of engines working on alcohol are employed for miscellaneous purposes in and about agriculture. These engines, however, are primarily of the high-compression slow-running type, and although the problem has been worked out very fully in its relation to this type, comparatively little work has been done on the high-speed type of engine employed in motor-car work. In France, races have been held and trials made on ordinary engines designed for petroleum fuel, running on mixtures of alcohol and benzine, and these experiments, rough and ready, sufficed to show that such a mixture was little, if any, behind the fuel it was displacing. Since the days when these were carried out great improvements in the efficiency of petroleum engines have been made, but these improvements are of such a nature that they would be of equal value in influencing the economy of the engine if run on benzine-alcohol mixture. It was to make a start in the type of investigation which is necessary if we are ever to be in a position to say whether alcohol is suitable for high-speed internal-combustion engines or not, that Messrs. Iliffe, of the "Autocar," empowered me to carry out certain tests which, at any rate, served to prove that on two types of modern petrol engines as much power can be generated when running on mixtures of equal parts of alcohol and benzine, and even when running on two parts of alcohol to one of benzine, as can be obtained from the same engine when running on petrol.

We know that alcohol can be used to better advantage in the ordinary type of engine, modified in the directions of a higher compression and provided with improved and modified carburetting appliances, but before we deal with the possibilities of designing engines specially modified to suit alcohol alone, it is better to find out what admixture of alcohol with another fuel can serve through being used in the existing unmodified motor, as a stepping-stone towards using mixtures containing alcohol for the most part, in engines which the process of natural development has rendered suitable for the new fuel. There is every reason to believe that any difficulties which may lie in the way of using alcohol as a motor-fuel are by no means insuperable, and, on the other hand, there are many theoretical, chemical, and physical reasons why alcohol should yield superior results. It can be employed without danger of pre-ignition under high compression, it can yield a much higher percentage of its available heat contents in the form of work, and for carburetting purposes it is much more homogeneous than the other fuels with which it competes. Assuming for the moment that methylated spirits can be used in admixture with benzine in the existing type of engine with slight modification to the carburetter, we open out at once the possibility of trebling the amount of fuel which could be obtained from coal alone, and as the use of such mixtures spreads manufacturers would undoubtedly so improve their carburetters and their engines that the proportion of benzine could be gradually reduced, and in this wise the almost insuperable difficulty of passing over from a type of engine of which millions are in existence to a modification thereof would be overcome.

Let us now turn to the second equally important aspect of the question, that of production, with which is intimately bound up the question of denaturing, and the incidence of the excise laws. Alcohol can be made from all starch and sugar-containing bodies, and is, indeed, made in all quarters of the world on an enormous scale—in Germany from potatoes, in France from beetroot, in Japan and China from rice, in the tropics from cane sugar, and elsewhere from starch-containing grains, such as barley and maize. It has been urged that although great efforts have been made in Germany to encourage the use of industrial alcohol it has made no headway as a motor-fuel. I have given the reasons for this elsewhere at considerable length, but, briefly, it suffices to say

here that the manufacture of alcohol from potatoes in Germany is regarded as a question of national economical interest, and that the alcohol which is employed for industrial purposes has been bounty-fed at the cost of duties imposed on alcohol used for potable purposes. The German motor manufacturer has always had a larger market outside his country than in it, and it is not likely that he would develop an engine type for a fuel only to be found in his own country and which would be useless outside its borders, particularly when the price of that fuel is regulated by a number of considerations which are entirely outside his knowledge and control. We know, for instance, that alcohol can be and is being produced in very considerable quantities from the residual of material left from the manufacture of what is known as sulphite wood-pulp, and we might reasonably ask how much of such residue is produced and what it would yield. We know that processes have been invented for the conversion of cellulose bodies, such as sawdust, into alcohol, and once a large market were made available no doubt the progress of such inventions would be much more rapid. At present the production of alcohol is hedged about with such restrictions, and the utilisation of the finished product hemmed in with so many difficulties, that the inventor is inclined to regard the whole field as unworthy of serious work.

In 1904 a Departmental Committee on Industrial Alcohol was formed. At that time petrol was about 1s. per gallon or less, and although the conclusions of this committee were adverse to immediate action, they were careful to leave an open door by stating that once it had been proved that alcohol could be employed with advantage in the modern motor or some modification thereof, and that the price of the competitive fuel rendered possible the application of alcohol, the Government would be prepared to consider the matter anew. Since that time, in this country, with the sole exception of the "Autocar" experiments, I am not aware that any practical steps whatever have been taken to demonstrate in how far alcohol can be employed in the modern motor so as to satisfy the first portion of their eminently reasonable request. Whatever may be the situation in this country and that requires and deserves immediate and close consideration there is not the slightest doubt that alcohol can be produced in large quantities and at reasonable prices in many of our Colonies.

It is in the lands of greater sunshine that starch and sugar products can most readily be produced, and this country has Colonies where the raw material for the production of alcohol can be produced in enormous quantities—the officials in these countries state, in practically limitless quantities, at a price equivalent to 3d. per gallon for 95 volume per cent. alcohol. To this must be added the cost of plant, fuel, and wages, items which grow less in proportion as the output increases. The Imperial Motor Transport Conference held in London in the summer of last year was attended by representatives of almost all our Colonies, and we can ask for no stronger evidence as to what our Colonies need, and think they can supply, than to turn to the final resolution passed at their meeting. Shortly, one may say that the final result of the conference was a demand that the subject of the production and utilisation of alcohol for motive purposes should be adequately investigated.

We have had in the last 10 years many committees which have dealt primarily or otherwise with the fuel question. They have gathered much information which will be available and valuable to future workers, but what is required at the moment is practical work. We must find out what are the minimum modifications to the existing type of motor which will render it capable of economically employing alcohol-benzine mixtures. We want to know the limiting composition of such mixtures before their use leads to a drop in efficiency which points to something different in design. There are a great number of fuel mixtures to be investigated with a view to finding out which, if any, possess peculiar physical properties, such as maximum vapour tension and maximum boiling-point, which would render them particularly suitable for our special purpose. We ought to work hand in hand with the Government authorities on the question of denaturants. There are rumours of new processes for the production of crude methyl alcohol which should be enquired into, since up to now the Government have insisted on a large percentage of this expensive material as a necessary ingredient in their denaturing mixture. Any reduction in the price of this crude methyl alcohol, at present obtained only from the distillation of wood, would be of importance in our new development.

We should have available statistics as to the output of starch containing bodies in all our Colonies; in fact, there are some years of difficult and expensive work before us, but without such work the development of the next 10 years in this direction will be that of the last 10 years. Does the mature consideration of the motor world, manufacturer, and user, and of the various committees of motor societies, lead us to believe that the petrol supply cannot keep pace with the growing demand? I think that question can be answered in the affirmative. Sir Boverton Redwood is the highest authority on this particular subject, and he has stated this to be his opinion. Is our coal supply likely to yield sufficient alternative fuel to make up the deficiency and to prevent prices still getting higher? In my opinion there is not the slightest doubt as to the inability of this source of supply to do what we require of it. Then what are the alternatives? The committee of the R.A.C. have admitted that alcohol would seem the only alternative if petrol and benzine fail us. The Motor Union Fuel Committee came to the same conclusion, and the Imperial Motor Transport Conference have confirmed this decision with no uncertain voice. The motor trade of this country is said to employ close upon half a million hands. The societies connected with the sporting aspect of the motor industry have incomes running into six figures. Surely, if these are convinced that that fuel upon which their whole existence depends is failing, they will do all that is necessary towards providing a substitute.

WORLD'S OUTPUT OF IRON AND STEEL.

A PARLIAMENTARY return issued on the 9th inst., gives details showing the production and consumption of iron ore and pig iron, and the production of steel in the United Kingdom and the principal foreign countries in recent years, and the imports and exports of certain classes of iron and steel manufactures. The probable world's output of iron ore in 1912 was about 152 million tons, or more than 5 per cent. above that of 1910. The principal producers were the United States, Germany, France, the United Kingdom and Spain, in the order given, these five countries producing about six-sevenths of the total output of the world. The following table gives the total output of iron ore in 1911 and 1912:—

	1911. Tons.		1912. Tons.
United States	43,877,000	...	55,150,000
Germany (including Luxemburg)	29,399,000	...	32,190,000
France	16,372,000	...	18,744,000
United Kingdom	15,519,000	...	13,790,000
Spain	8,633,000	...	—
Russia (excluding Finland)	6,882,000	...	8,054,000
Sweden	6,055,000	...	6,593,000
Austria-Hungary	4,640,000	...	2,880,000
Canada	188,000	...	156,000
Belgium	148,000	...	165,000

In the case of Germany there has been a continuous increase in the output since 1908, and in 1912 it was well above that of any previous year. In the United Kingdom and in Spain the output in 1909 was even less than in 1908, but the British output in 1911 was only 1 per cent. below that of 1907. Owing to the dispute in the coal trade, however, through which the majority of the blastfurnaces in the country were stopped with a considerable slackening in the demand for ore, the output in 1912 was the lowest recorded since 1904. In France the rapid increase shown in the production for several years before 1908 has continued, and the output in 1912 was over 89 per cent. above that in 1908.

The ore resources of the world as given in the report are based on an estimate made at the International Geographical Congress at Stockholm in 1910. It was then estimated that the total actual resources of iron ore existing in deposits that can at present be worked at an economic profit amount to 22,408 million tons, representing 10,192 million tons of iron. This total would supply the requirements of the world for considerably less than two centuries, even were the present rate of output not exceeded on the average. The actual resources of the principal ore-producing countries are estimated to be, in the United States 4,258 million tons, the equivalent in metallic iron being 2,305 million tons; in Germany and Luxemburg 3,878 million tons, estimated to yield 1,360 million tons of metallic iron; in the United Kingdom

1,300 million tons, equal to 155 million tons of metal; in France 3,300 million tons, equal to 1,140 million tons of metal; and in Spain 711 million tons, equal to 349 million tons of metal. In addition, the potential resources of the world not yet developed are estimated, so far as they can be calculated in figures, to amount to 123,377 million tons of ore, representing 53,136 million tons of iron. Further, very large supplies of iron ore are understood to exist in China, Canada, and other countries, but no definite information is at present available as to the extent.

The world's production of pig iron in 1912 was about 72 million tons, the United States, Germany, and the United Kingdom accounting for about seven-ninths of the total. The United States output was 29,727,000 tons; Germany's, 17,582,000 tons; and the United Kingdom's, 8,751,000 tons. For the first half-year of 1913 the figures for the three principal countries were: United States, 16,489,000 tons; Germany, 9,414,000 tons; United Kingdom, 5,411,000 tons. For the last half-year the figures are estimated at: United States, 14,600,000 tons; Germany, 9,600,000 tons; United Kingdom, 5,069,000 tons. The total exports of pig iron from the United Kingdom, on the average of the five years 1908 to 1912, amounted to 1,220,000 tons per annum, or 14 per cent. of the total British production. The total exported from the 10 chief countries averaged in the same period about 2,374,000 tons per annum, or 4 per cent. of the total produced in those countries.

The combined output of steel in the United Kingdom, Germany, and the United States, in 1912, exceeded 55 million tons; and the world's output may be estimated at between 71 and 72 million tons. The output of the three principal countries in 1912 was, however, remarkable, being 22·6 per cent. above that of 1911, and 32·1 per cent. above that of 1907. The steel production in France is stated to have been about 1,611,000 tons more in 1912 than in 1907; that of Belgium 978,000 tons more; and that of Austria-Hungary 965,000 tons more.

The quantity of steel (5·3 million tons) produced by the open-hearth process in the United Kingdom in 1912 was about 3½ times that produced by the Bessemer processes (1·5 million tons). In Germany, on the other hand, the preponderance was reversed, nearly three-fifths of the total production (9·8 million tons out of 17 million tons in 1912) consisting of Bessemer steel. In the United States the output of Bessemer steel had, since 1908, been increasingly exceeded by that produced by the open-hearth process, most of the new steel-making plant erected in that country being of the open-hearth variety. Nearly the whole of the German steel was basic steel, the native ores being used, for the most part, such as are suitable for the Gilchrist-Thomas process.

Only about 3½ per cent. of the open-hearth steel produced in the United States in 1912 was acid steel, whereas the entire output by the Bessemer process was, and always had been, acid steel. In the United Kingdom for various reasons acid steel was much in demand, and over three-fifths of the steel produced in 1912, whether by the Bessemer or open-hearth process, was acid steel; but in the last 10 years the output of basic steel had increased much more rapidly than that of acid steel.

In 1912 the exports of iron and steel from the United Kingdom were in the aggregate in excess of those for the preceding four years. The total production of steel in the United Kingdom increased from 2,920,000 tons in 1892 to 6,903,000 tons in 1912. In Germany in 1900 (the first year for which figures are available) the production was 6,539,000 tons. In 1912 it had increased to 17,024,000 tons. In the United States in 1892 the production was 4,928,000 tons. In 1912 it had increased to 31,251,000 tons.

In Great Britain there were in 1878 18 firms making open-hearth steel, with 100 furnaces, in 1890 there were 61 firms, with 329 furnaces, in 1903, there were 94 firms, with 512 furnaces, and in 1911 there were 105 firms, with 543 furnaces, of which 113 were not in operation. At the beginning of 1911 there were 407 acid and 136 basic furnaces, compared with 417 acid and 95 basic furnaces in 1903. The total capacity of the furnaces in existence in 1911 was 16,730 tons per heat; 97 furnaces had capacities ranging up to 20 tons, 141 between 20 and 30 tons, 136 between 30 and 40 tons, 99 between 40 and 50 tons, and 70 over 50 tons. In 1870 there were 19 firms making Bessemer steel, with 71 converters, in 1890 there were 32 firms, with 113 converters, in 1905 there were 19 firms, with 76 converters.

THE ENGINEERING PROBLEM OF ELECTRIFICATION.*

BY A. H. ARMSTRONG, M.AM.INST.E.E.

(*Concluded from page 127.*)

MOTOR and gears are assumed to be of equal efficiency for both split-phase and direct-current, as the advantage of one type motor over the other will be small at best and will not materially affect the values given. Blower efficiency is based upon the fan blower required to cool the motors and auxiliaries taking 30 kw. split-phase and 20 kw. direct current. Starting resistances consume a portion of the power required to start the train, and efficiency of the locomotive is based upon the assumption that the train is started from rest once in two hours. This starting resistance loss is greater with the split-phase than with the direct-current locomotive, being twice as large up to speeds of 15 miles per hour on ruling grade and four times as large up to speeds of 30 miles per hour on level track. Phase converter efficiency is determined by assuming that the capacity of the converter will approximate 75 per cent. of that of the four motors it controls. Transformer efficiency values given require no comment.

Wheel correction is determined as follows: Induction motors run at nearly synchronous speed, the slip being proportional to the total secondary non-inductive resistance, hence all wheels upon the same locomotive must be very closely of the same diameter in order to ensure equal loading of the several motors. When one pair of wheels is turned, all must be turned equally. This would not be a very serious handicap were it not for the fact that several locomotives will operate in the same train, thus necessitating equal wheel diameters on all such locomotives. It is therefore evident that all locomotives must be interchangeable and any group of two or more be capable of running in the same train or the operating department will be seriously handicapped. The diameter of new and turned wheels may vary fully 4 per cent., an amount sufficient to cause a prohibitive load distribution between motors. Hence it is proposed to install a variable secondary resistance and so adjust this resistance in the several motor secondaries that all wheel peripheral speeds will conform to the average diameter of new and worn wheels. This will entail an average loss of, say, 2 per cent. when operation has continued long enough to require turning wheels to the minimum diameter allowable. Direct-current motors have such a variable speed characteristic as to require no adjustment for varying wheel diameters. Weight efficiency is a relative value based upon comparison with the direct-current locomotives taken at 100 per cent.

Comparative Weight Efficiency—Freight Locomotives.

	Split-phase.	2,400 Volts Direct Current.
Rated T.E. on ruling grade	36,000lbs.	36,000lbs.
Gross train weight	750 tons	750 tons
Trailing train weight	615 tons	650 tons
Per cent. trailing to gross	82 per cent.	86·7 per cent.
Weight efficiency	94·7 per cent.	100 per cent.

On level track it is assumed that pushing locomotives will be dropped and train weight per road locomotive will be double the ruling grade values. On this basis the split-phase locomotive weight efficiency will be 97 per cent. for level track runs. Both values of split-phase locomotive weight efficiency are based upon the assumption that locomotives will be loaded to 100 per cent. capacity on ruling grades. As such will not always be possible in regular operation, it is evident that the values quoted above will be lower under actual service conditions. The combined efficiency of the complete locomotive shows that the split-phase freight locomotive will demand 15 per cent. more power input from the trolley than a direct-current locomotive of equal hauling capacity and similar mechanical drive.

For passenger service it is reasonable to expect the locomotive running gear to be so constructed as to permit maximum speeds approaching 75 miles per hour without danger of derailment or exceeding safe limits of motor and drive construction. Neither of the forms of construction in

*Abstract of paper read before the Canadian Society of Civil Engineers, December 18th, 1913.

Fig. 3 are well adapted for very high speeds, and to secure good running qualities it is probably necessary to adopt different types of construction for freight and passenger locomotives, however desirable it may be from an operating standpoint to have them interchangeable. With direct-current motors several forms of construction are available that will all operate successfully at high speeds. The most efficient construction is unquestionably to mount the motor armatures upon the driving axles and eliminate the losses, weight, and complications of any form of mechanical drive. It is assumed in this comparison that gearless construction will be adopted for direct-current high-speed passenger locomotives.

The split-phase locomotive motor is of the multi-phase induction type and not adapted to gearless construction except by the introduction of quills and springs. This form of construction has not been so successful in operation as to justify considering its general adoption. It is assumed therefore that in order to get a locomotive of good riding qualities at high speeds, it is necessary to resort to side rod drive from a jack shaft and house the motors in the cab. In this comparison it is assumed that motors drive the jack shaft through gears rather than by rods, as offering a lighter form of construction requiring less space. The same form of drive is equally available with direct-current motors, but gearless construction offers great advantages such as extreme simplicity, accessibility, and high efficiency, so that comparison will be based upon geared side rod split-phase and gearless direct-current motor locomotives.

Passenger Locomotive Efficiency—Detailed Comparison.

	Split-phase.		2,400 Volts Direct Current.	
	Ruling Grade	Level.	Ruling Grade.	Level.
	Per cent.	Per cent.	Per cent.	Per cent.
Motors and gears	89·3	83·0	87·5	94·0
Blower	97·8	84·8	97·9	95·5
Starting resistance	98·6	97·8	99·2	99·3
Phase converter	96·3	94·0	—	—
Transformer	98·0	96·0	—	—
Wheel correction	98·0	98·0	—	—
Weight efficiency	92·5	92·5	—	—
Jack shaft	97·0	93·0	—	—
Side rods	97·0	93·0	—	—
Combined efficiency	69·3	54·5	85·0	89·2
Average of grade and level	61·9 per cent.		87·1 per cent.	

It appears reasonable to expect the efficiency of mixed passenger and freight locomotive operation to approximate 85 per cent. for direct current, and not much exceeding 68 per cent. to 70 per cent. for split-phase locomotives. This efficiency in each case is based upon that portion of the run during which power is delivered to the locomotive. If transformer, phase converter, and blower are kept running during coasting periods or when standing, the stand-by losses thus introduced will seriously reduce the all-day efficiency in commercial operation. It is evident that such stand-by losses are much greater in the split-phase than in the direct-current locomotive, and the 20 per cent. saving in power for mixed freight and passenger service credited to the direct-current motive power may be materially increased in actual service.

Before concluding the general discussion of the locomotive it is necessary to touch upon the question of braking. One of the strongest arguments advanced for the adoption of the induction motor locomotive is that this type of motor offers an ideal electric brake by reversing its function on down grade and returning power to the trolley circuit. A regenerative braking method of control has been perfected for use with the direct-current motor which offers even greater advantages in service operation than induction motor braking. Just as the direct-current locomotive is the more efficient in hauling a given trailing tonnage, so also it will return to the system a larger percentage of the mechanical power given the locomotive by the descending train. Hence whatever claims are advanced for regenerative electric braking with the split-phase locomotives are even more applicable to the direct current type.

Referring again to Figs. 1 and 2, showing the general plan of distribution respectively for the split phase and direct current systems, it is of interest to compare the two in order to see how much of the split-phase locomotive loss is recouped by its more efficient distribution system. The following comparison is therefore submitted.

Efficiency of Distribution System—Detailed Comparison

	Split phase.	2,400 Volt Direct Current.
	Per cent.	Per cent.
Step-down transformers	97·5	96·5
Motor generator sets	87·0	81·0
Step-up transformers	97·5	—
Railway transmission line	96·0	96·0
Line transformers	96·0	—
Protective transformers............	96·0	—
Trolley, track, and feeders	96·0	88·0
Combined efficiency	70·5	66·0

Protective transformers appearing in above table are for the purpose of neutralising the inductive disturbance caused by single-phase trolley upon neighbouring telephone, telegraph, and signal circuits.

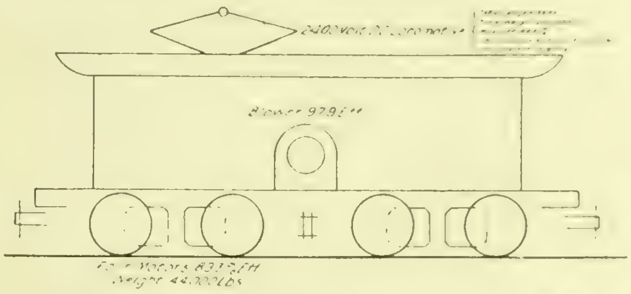


Fig. 3. Comparative Elevations of Split phase and 2,400 Volt Direct-current Locomotives of Equal Capacity.

Total Efficiency—Distribution System and Locomotive.

	Split-phase.	2,400 Volt Direct current
Freight Service—	Per cent.	Per cent.
Distribution	70·5	66·0
Locomotives..................	73·1	84·3
Combined efficiency	51·5	55·7
Passenger Service—		
Distribution	70·5	66·0
Locomotives..................	61·9	87·1
Combined efficiency	43·6	57·5

There is every reason to expect that the split-phase system will demand fully 15 per cent. or more power input than the direct-current system of 2,400 volts for equal trailing tonnage movement, actual figures depending upon the proportion of freight and passenger tonnage. This figure is based upon 60-cycle power supply, for the reason that many of the immediate electrification projects under construction or contemplated are located in territories where this frequency is firmly established. Where 25 cycles is available, single-phase power may be taken direct from the 3 phase supply, provided phase and voltage balance is maintained by suitably located sub stations containing step down transformers and phase converters. Direct current supply will be more efficiently obtained through rotary converters in place of motor generator sets. The efficiency of the distribution system, as given above, will therefore need correction for 25 cycle power supply, but will result in no material change in the relative efficiency figures quoted for the two systems.

Installing a power-house to generate single-phase current at 25 cycles or less introduces all the serious handicaps encountered in single-phase generation, as well as raises questions of general expediency and adequate return on the capital invested in a power plant devoted to supplying railway load only. Advocates of single-phase trolley distribution have sometimes failed to fully consider the question of power supply

available as having any bearing upon the broad question of electrification. Not every railway is so situated by reason of character of load, cheap fuel, or other favouring local conditions as to justify the large expenditure for a generating station containing ample reserve capacity. Appreciating fully the somewhat higher efficiency of the split-phase distributing system if single-phase power of 25 cycles or lower is available, this matter is so local in its character that it may properly be looked upon as a special condition applying only to favoured and restricted localities.

A study of the general plan of distribution as given in Figs. 1 and 2 discloses the fact that where 60-cycle power supply is available at attractive rates, the general statement can be safely made that the total amount of electrical apparatus is greater and, therefore, the first cost higher and efficiency lower with the split-phase than with the direct-current locomotive system. Nor is this statement modified to any extent in the event that power supply is obtained from a 25-cycle 3-phase source, as it will be the exception rather than the rule that any power company will be found willing to furnish single-phase power from its balanced 3-phase circuit when the pernicious effect upon the general distribution system of a violently fluctuating low-power factor single-phase load is fully understood. Some corrective device like a phase converter must be introduced, and its first cost and efficiency are both comparable to the rotary converters which are permissible with 25-cycle supply to secure direct current. It would seem, therefore, that the complication of the split-phase locomotive system renders it inherently more expensive to install and less efficient to operate. This is due largely to the fact that substations are required both on the ground and also in the locomotive cab itself.

The single-phase trolley circuit, irrespective of the type of locomotive it may supply, constitutes in itself a most serious handicap to the adoption of any type of alternating-current locomotive. Neighbouring circuits of all kinds are practically put out of commission by static and inductive disturbances unless adequate protective measures are introduced. No method of complete protection has as yet been perfected, although many schemes have been proposed that are partially successful. The elaborate and expensive apparatus now being installed upon one of our important single-phase railways will soon be in operation and is expected to give relief from the present serious conditions obtaining. As the inductive interference of the single-phase trolley is proportional to the intensity of the current and distance it is transmitted, it is to be expected that a maximum disturbance will result in the case of mountain grade divisions where the current input to trains approaching 3,000 tons gross weight is several times that thus far met with in any single-phase trolley installation now operating. No cost estimate of single-phase trolley systems is, therefore, complete without including a liberal allowance for telephone and telegraph protective devices. This cost will probably not be less than £500 per mile of route and may even greatly exceed this figure. Even with such an expenditure, no assurance is at hand that hazard to employés and interference with service will be entirely eliminated, and until more exact knowledge of this whole situation is available, single-phase trolley interference constitutes the greatest handicap to the adoption of any alternating-current locomotive system of operation.

This paper is largely devoted to a comparison of alternating and direct-current motor locomotives, as lack of appreciation of the fundamental facts involved has perhaps been the basis of the false hopes raised as to the possible advantages resulting from the installation of the single-phase trolley. It surely does look attractive to install a system employing 15,000 volts on the trolley, no feeder copper, and no rotating substation apparatus. But investigation discloses the fact that the single-phase trolley is a decided menace to neighbouring circuits, feeder copper is required for return circuit, substations are comparable as to first cost and efficiency with direct-current substations, and finally, the alternating-current locomotive of the most promising type, the so-called split-phase combination of induction motors, transformer and phase converter is heavy, expensive, complicated, and inefficient to a degree that would not be tolerated in direct-current construction. Assuming that the favourable results of factory experiments are borne out in the success of later commercial operation, there appear to be no controlling advantages of alternating-current locomotive traction which cannot be secured at less expense and with greater reliability in operation with direct-current motive power.

Until the adoption of inter-pole motor construction made it entirely practicable to build direct-current motors for high potentials, there was some justification for considering alternating trolley systems as offering the only means of changing from steam to electric motive power at a reasonable first cost. The high-voltage direct-current motor has now been developed, built, and proved completely successful under the most exacting service conditions. The trolley potential has been raised to 2,400 volts, which seems sufficiently high to ensure a distribution system of reasonable first cost and not too high to handicap the locomotive as regards its first cost, reliability, and operating efficiency. Experimental results already obtained with direct-current apparatus tested at potentials higher than 2,400 volts indicate that no construction difficulties apparently exist, and the installation of a higher voltage becomes an economic question rather than an engineering problem. With 2,400 volts direct current both protected third-rail construction and multiple-unit car operation are feasible. The third rail offers advantages in accessibility and low cost of maintenance on single track roads and multiple-unit car operation is without question the proper way to take care of local traffic. Furthermore, 2,400-volt equipments can be successfully operated upon the lower voltage terminal zone that local restrictions may make necessary.

The direct-current motor is fully able to meet all the requirements of the heaviest passenger and freight train operation, as proved by the entirely successful installations now running, and which afford convincing facts upon which statements of costs and operation are based. No such condition exists with any alternating locomotive system, and such operating facts as are obtainable are not of such a nature as to inspire confidence in selecting such a system to meet the exacting requirements of heavy electric railroading. The engineering facts presented herewith are offered with the purpose in view of clearing the engineering atmosphere preparatory to the serious work that seems to lie immediately before us, that is, the problem of where it will pay to replace the steam engine by the electric locomotive.

AIR BRAKE TESTS.

IMPORTANT improvements in the braking of heavy passenger cars were described in a paper read before the American Society of Mechanical Engineers, New York, on the 10th inst., by Mr. S. W. Dudley, of Pittsburg. Tests were conducted jointly by the Pennsylvania Railroad and the Westinghouse Air Brake Company, and the results are considered the most important recent contribution to the subject of air brakes. A train of 12 steel cars at 60 miles per hour stores up 224 million foot-pounds of energy. This is sufficient to raise the entire train 120ft. With prevailing brake equipment such a train would be stopped by an emergency application in a distance of 1,600ft. to 2,200ft., according to the truck rigging and brake shoe design. The tests show that this distance has actually been reduced to 1,000ft., or to within the length of the train. This result has been attained by improvements in the truck brake design involving the clasp brake, having two shoes per wheel, and the location of the brake shoes with reference to the horizontal centre line of the wheels, in addition to improved methods of applying the air brakes quickly and simultaneously and at a high pressure. The tests emphasize the possibilities of improvement in efficiency and economy in regular service operation by proper attention to design and installation, in order to permit the realisation of the flexibility of improved air-brake apparatus. These improvements centre in the electric control of the brakes, giving quick, simultaneous, and responsive action. The electric control has opened the way for maximum effect in practice of improvements in practically all the factors involved in air-brake apparatus, all of which are covered in the development represented by these tests. The tests constitute a progressive development of brake rigging and brake shoes in connection with the scientific study of the air brake as a whole

The Institution of Civil Engineers.—At a meeting of this Institution held on the 11th inst., a paper was read by Mr. Adam Scott, M.Inst.C.E., on "The New Harbour Works and Dockyard at Gibraltar." The paper dealt with the new works up to the end of 1905, when the author's connection with them ceased, and when all the principal portions of the works were completed.

BRASSES AND MUNTZ-METAL.

LOW-BRASS, high-brass, Muntz-metal, bronze and gilding are the common brass mixtures used in the trade, although there are a number of others less extensively used. High-brass is the most common variety and is known as "common brass," and it contains all the way from 61 per cent. to 70 per cent. of copper (the remainder being zinc). Spinning-brass, cartridge-brass, dipping-brass, drawing-brass, and screw-rod are all high-brass. Screw-rod contains several per cent. of lead in order to make the brass cut freely, but the other varieties are free from it. Low-brass is a softer variety than the high-brass and is used where more stretch is required in drawing or spinning. It is also used for brazing, as it melts at a higher temperature than brazing solder, which is not the case with the high-brass mixtures. Low-brass contains from 75 per cent. to 80 per cent. copper and the remainder zinc. If more copper is contained in the mixture, the colour begins to change to an orange. The colour of low-brass is a greenish-yellow and it is the most beautiful of any of the mixtures.

Muntz-metal is a brass mixture containing 60 per cent. of copper and 40 per cent. of zinc. It is used because it will roll hot and is cheaper than the other mixtures. It is far less used at the present time than formerly, when it was employed for sheathing wooden ships. It has been found to disintegrate under such conditions, however, and copper is now used in its place. Any brass mixture that contains even more zinc is also a Muntz-metal mixture, as it will roll hot. The now well-known extrusion-metal is an example of this kind, and it contains 55 per cent. of copper and 45 per cent. of zinc.

Gilding is a gold-coloured mixture of copper and zinc and consists of 90 per cent. of copper and 10 per cent. of zinc. It has a gold colour, although not as rich as pure gold or its alloys. It is used when an imitation of gold is required, and there are many instances in which it is employed, such as, for example, in the manufacture of cheap jewellery.

Bronze is a gilding mixture with the addition of a little tin, and the favourite mixture is 90 per cent. copper, 9 per cent. zinc, and 1 per cent. tin. For the majority of purposes, however, the straight gilding answers equally as well and is generally employed. A number of other mixtures of bronze are used, of course, depending upon the use to which they are to be put. Ordinary bronze for rolling, however, is the mixture previously given.—"The Brass World."

INDUSTRIAL AND TRADE NOTES.

Light Railway.—The Board of Trade have recently confirmed the undermentioned Order made by the Light Railway Commissioners: Merthyr Tydfil Light Railway (Amendment) Order, 1914, amending the Merthyr Tydfil Light Railway Order, 1899.

Closing of Rolling Mills.—By the closing down of the Newport Rolling Mills of Messrs. J. Hill & Co., Middlesbrough, about 550 men have been thrown out of employment. It is understood that the site on which the works stand has been acquired by Sir B. Samuelson & Co., Ltd., and the latter company does not intend to carry on the rolling mills.

Amalgamation of Weighing Machine Firms.—Two well known firms of weighing machine and scale manufacturers, W. & T. Avery, Ltd., and Henry Pooley & Son, Ltd., have, we understand, arranged to amalgamate. Subject to approval of the shareholders the directors of Henry Pooley & Son, Ltd., have approved of the terms of an agreement for the sale of the company's business as from September 30th, 1913, to W. & T. Avery, Ltd.

Board of Trade Appointments.—The survey staff of the Marine Department of the Board of Trade is shortly to be increased by a small number of additional appointments to each of the three grades—engineer surveyors, ship surveyors, and nautical surveyors. The salaries commence at £200, rising to £400 per annum, and surveyors are eligible for promotion to higher posts, rising to £500 per annum, &c. Intending applicants should apply to the Assistant Secretary, Marine Department, Board of Trade, Whitehall Gardens, London, S.W.

Infringement of Messrs. Reddaway's Trade Mark.—In the Lancashire Chancery Court, Monchester, on Monday last, Messrs. F. Reddaway & Co., Ltd., of Manchester, applied for an injunction to restrain Messrs. John Taylor & Co. (Waterfoot), Ltd., from infringing a registered trade mark, and from using the words "camel hair" as descriptive of belting not of the plaintiffs' manufacture. The plaintiffs were well known manufacturers of "camel hair" belting, and they complained of the use of that term by the defendants. A writ had been issued and notice of motion served with a number of affidavits. The defendants now consented to a perpetual injunction, to pay a fixed sum of damages, and also the taxed costs.

Trade Circulars.—We have received from the Cambridge Scientific Instrument Company some interesting circulars relating to thermometers of special kinds for various industrial purposes and especially engine and boiler work, with all kinds of attachments to permit of their application in positions that are not accessible to instruments of the ordinary kind. The Sun Electrical Company, Charing Cross Road, London, send us some circulars and price lists of electric lamps, enclosed waterproof bells for signals and fire alarms, &c. Also of small motors, both A.C. and D.C. type, for small drills, sewing machines, and the multitude of little appliances for which there is a considerable demand. Barimar, Ltd., 10, Poland Street, Oxford Street, London, W., send us an interesting little booklet entitled "Guaranteed Welding Repairs by Barimar Process," containing illustrations of aluminium crank chambers, cylinders, crank shafts, gear wheels, &c., which have been permanently repaired by the Barimar welding process.

Employers and the Trades Disputes Act.—At a meeting of the Employers' Parliamentary Council, held at 27, Victoria Street, Westminster, on the 4th inst., to consider the grave industrial situation due to the Trades Disputes Act, and the unchecked conspiracy of labour unionism against private freedom and public welfare, arrangements were made to hold a mass meeting of representatives of the Associations of Employers connected with the various industries in the United Kingdom to urge upon the Government the need for an enquiry into the working and the effects of the Act, to determine whether the present unlimited area in which picketing in unlimited numbers may be carried on should not be restricted and the number of pickets regulated by Statute, whether combinations for disorganising trading and social conditions should not be made unlawful, and whether it is not of national interest that all unions should be subjected to the ordinary law of the land, and made responsible, like all other classes, for their actions.

State-owned Railways.—Railway nationalisation formed the subject of a conference at the Memorial Hall, Farringdon Street, on Saturday last, when 215 societies—trade unions, political organisations, co-operative societies, and other bodies—were represented by the 615 delegates present. The meeting was called by the Railway Nationalisation Society. Sir J. Compton Rickett, who presided, said the case for nationalisation was growing stronger day by day with the increase of population and the vast industrial growth of the country. The competition between different companies forced economies upon them, which tended to encroach upon the margin of safety. A national system was the only one in which a satisfactory solution could be found. Mr. Emil Davies moved the following resolution: "That having regard to the importance of cheap transit and transport to all sections of the community, and in view of the fact that any advantage that may have accrued from competition between the railways is now exhausted, this conference is of opinion that a national united system would make for economy, better service, and public safety." The resolution was carried with the deletion of the words "and in view of the fact that any advantage that may have accrued from competition between the railways is now exhausted." A clause was also added urging the Government to consider the question at the earliest possible moment.

Nottingham Society of Engineers.—At a meeting of this society, held on Wednesday last, a paper on "Defective Boiler Mountings" was read by Mr. F. W. Sisson, of the Vulcan Boiler and General Insurance Company. The author dealt in an interesting manner with safety valves, water gauges, pressure gauges, blow-off cocks and pipes, fusible plugs, stop valves, feed valves, and manholes, directing attention to defective types, and emphasising the importance, in the interests of public safety, of employing only fittings of a reliable type.

Junior Institution of Engineers: North-Western Section.—A meeting of this Section was held in Manchester on the 6th inst., when a discussion on "Systems of Lighting" was opened by Mr. George White, who was strongly in favour of incandescent electric lights. In the discussion which followed, various members advocated the claims of most of the other known systems of lighting. The following took part in the discussion: Messrs. M. Hird, N. G. Smith, A. W. Cowan, E. Eaves, E. le Low Lamb, A. H. Black, E. J. Christian, W. B. Dale, C. H. Prichard, and Bruce.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1912.

Turbo-electric machines. Rolfe. 23689.
Drills and drill holders. Scott. 26452.
Atomiser for oil engines. Griffin. 29015.

1913.

Steering and controlling steamships. Whittaker & Cooper. 1109.
Mould-manipulating tables used in casting of metals. Ferman, and Ferman & Co. 1517.
Joint making ring for manhole doors. Snowden. 1543.
Carburetters for internal-combustion engines. Beswick. 1546.
Apparatus for bending and welding chains. Wilke. 1641.
Back facing devices for lathes. Miller & Gisholt Machine Company. 1731.
Wrought-metal wheels. Brown, and Chas. Mackintosh & Co. 1760.
Gas-fired furnaces. Tooth. 1772.
Formation of gear-wheel teeth. Parsons & Cook. 1844.
Fluid flow meters. British Thomson Houston Company. 1914.
Safety appliances for pit cages. Anderson. 1941.
File-cutting machines. Law & Baines. 2444.
Carburetters. Bouteille. 3381.
Friction clutches and couplings. Taylor. 4426.
Consuming smoke in steam boilers. Whiteley. 5270.
Washers for locking nuts. Franklin & Beall. 5561.
Water meters. Brodie. 5894.
Valve tappets for fluid pressure engines. Fenn. 7078.
Conveyers for use in coal mines. Bowman & Jackson. 7201.
Wrenches. Moss. 7468.
Starting devices for internal combustion engines. Kettering. 7543.
Automatic couplings for vehicles. Street. 8496.
Apparatus for operating the points of railways and tramways. Thomson. 8728.
Fluid operated engines. Rector. 9452.
Vacuum brake apparatus for railway vehicles. Gresham. 10148.
Fluid compressors or pumps. Richards. 10678.
Liquid fuel. De Cosmo & Quinaux. 11167.
Metal plate bending machines. A. Kinghorn & Co., and Walker. 12185.
Steam engine indicators. Clyde & Dobbie McInnes, Ltd. 13032.
Water tube marine steam boilers. Soc. Anon. Italiana Gio. Ansaldo & Co. 13313 and 13314.
Boring tools. Nevin. 13889.
Mufflers for engine exhaust. Fairweather. 13931.
Four cycle internal combustion engines. Freiberg, Freiberg, and Petzsche. 14090.
Means for supplying heated supplemental air to internal combustion engines. Johnson. 14508.
Vaporizers or heaters. Mellersk Jackson. 14625.
Internal combustion engine. Beyer. 14980.
Apparatus for lighting railway carriages with gas. Julius Pintsch Akt.-Ges. 15038.
Oil burners. Heinsen. 15631.
Elastic fluid pumps. Miles. 15662.
Process of rolling thin-webbed I and H beams by means of universal mills. Deutsch Luxemburgische. 16479.
Liquid fuel injection device for internal combustion engines. Veltman. 16902.
Steam or gas turbines. Aktiebolaget Ljungstroms Angturbin. 17335.
Punching machines. Cameron, and John Cameron, Ltd. 17554.
Automatic air brake apparatus for railway trains. Aird. 18345.
Rotary cranes. Kimmel. 20507.
Atomising apparatus for washing, purifying, and cooling gases. Theisen. 21427.
Lubricators. Knebel. 21760.
High speed rotating bodies. Soc. Anon. pour l'exploitation des procédés Westinghouse Leblanc. 22256.
Variable speed gearing. Pedersen. 22581.
Two-stroke cycle engines. Hounsfield. 23065.
Expansion joints for steam pipes. Drewry. 25110.
Preventing accumulation of fire damp in coal mines. Kempermann. 25318.
Two stroke internal combustion engines. Nydahl. 26052.
Ball bearings. Aktiebolaget Svenska Kullagerfabriken. 26064.
Stop valves or cocks. Kilburn, and J. Hopkinson & Co. 26450.
Grinding machines. Churchill Machine Tool Company, March, and Asbridge. 26559.
Mechanical stokers for boiler furnaces. Marcotty. 27057.

ELECTRICAL, 1913.

Supports for the filaments of incandescent lamps. Roux and Sanchez. 1442.
"Dimmers" for electric lamps. Middlemiss. 1467.
Electric motor control systems. Siemens Bros. Dynamo Works, Ltd., Lydall, and Duke. 1591.
Telephone exchange systems. Western Electric Company. 1902.
Rheostats for controlling electric motors. Swan. 6226.
Insulators for high tension oil immersed electrical apparatus. Bitter & Weissberg. 7656.
Method of operating rotary converters. Railing & Garrard. 10841.
Apparatus for automatically starting or braking electro motors. Delvenne. 11135.
Metallic vapour electric lamp. Kerschbaum. 11991.
Arrangements for converting continuous currents into isochronuous undulatory currents. Soc. des Telegraphes Multiplex. 14122.
Controlling means for electric motors. Otis Elevator Company. 15571.
Telephone exchange systems. Western Electric Company. 16267.
Manufacturing an electric lamp filament containing cobalt. Kanazawa. 16481.
Induction coils. Hiorth. 22156.
Discharge tube with incandescent cathode and enclosed vapour forming body. Allgemeine Elektricitats Ges. 22816.
Electric fuses. Young. 27641.
Sparking plugs. Pognon. 28267.
Arrangements for destroying residual magnetism. Fried. Krupp Akt.-Ges. 28715.

METAL QUOTATIONS.

TUESDAY, FEBRUARY 10TH.

Aluminium ingot	86/- per cwt.
,, wire, according to sizes, &c. ......from	112/- ,,
,, sheets ,, ,, ... ,,	112/- ,,
Antimony	£27/10/- to £29/10/- per ton.
Brass, rolled	7½d. per lb.
,, tubes (brazed)	9⅝d. ,,
,, ,, (solid drawn)	8¼d. ,,
,, ,, wire	7⅝d. ,,
Copper, Standard	£65/17/6 per ton.
Iron, Cleveland	51/9 ,,
,, Scotch	57/9 ,,
Lead, English	£19/15/- ,,
,, Foreign (soft)	£19/12/6 ,,
Mica (in original cases), small	6d. to 3/- per lb.
,, ,, ,, medium	3/6 to 6/- ,,
,, ,, ,, large	7/6 to 11/- ,,
Quicksilver	£7/10/- per bottle
Silver	$26\frac{9}{16}$d. per oz.
Spelter	£21/7/6 per ton.
Tin, block	£183/15/- ,,
Tin plates	13/3 ,,
Zinc sheets (Silesian)	£25/-/- ,,
,, (Stettin ; Vieille Montagne)	£25/2/6 ,,

Coal Dust Explosions in Mines.—Prof. H. B. Dixon delivered a lecture at Manchester University on Monday last, on experiments made at Eskmeals, Cumberland, on the problem of explosions in mines with a view to their prevention. The Government, he said, spent a considerable sum of money in carrying out these experiments at Eskmeals. The chief thing they had done up to the present was to test under what conditions coal dust spread throughout a mine could be stopped from igniting, what were the conditions for producing the initiatory explosion, and how could they be prevented. They found that once the explosion had travelled some distance it behaved like a gas mixture, increasing in violence and in velocity, and that the flame was more difficult to extinguish than a flame that had only just started on its course. They found that the method that was first tried on a practical scale by Sir W. E. Garforth, at Altofts—that of mixing coal dust in the mines with inert dust was effective in stopping the initiation of an explosion. If they spread inert dust all over a mine they could not fire it because there would not be a sufficient run of flame to set it on fire or propagate an explosion. The inert dust remedy really consisted in this: that the same cause that threw up the coal dust into a cloud and made it possible to ignite it, also threw up the inert dust, which could put out the flame. Prof. Dixon said the Government had granted sufficient money to allow experiments to be continued for another year.

The Mechanical Engineer.

AN ILLUSTRATED WEEKLY JOURNAL Vol. 33, No. 839

Edited by
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Telegrams: "Scientific," Manchester.
Telephone No. 6055 City.

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Advertisements, displayed, for insertion in current issue should reach our Manchester office not later than first post Tuesday morning, and small prepaid advertisements not later than first post Wednesday morning.

The Explosion of Compressed Gas Cylinder on the "Mauretania."

THE evidence at the adjourned inquest held at Liverpool on Friday last on the four men who were killed by the bursting of a bottle of compressed gas on board the Cunarder "Mauretania" on the 26th ult. while some workmen were conducting brazing operations in connection with repairs to one of her turbines, illustrates once more the fallibility of the human element and the occasional disastrous results of it in mechanical operations, in spite of all precaution. Compressed oxygen, hydrogen, coal gas, &c., are extensively employed for welding and illuminating purposes, and, as oxygen and hydrogen form a dangerously explosive mixture, precautions have to be taken to differentiate cylinders containing these gases, with a view to prevent them getting mixed when cylinders are being recharged. Cylinders containing hydrogen, or coal gas (a hydrogen compound), are painted red and fitted with screw nozzles having a left-handed thread; while cylinders containing oxygen, or air (a mixture of oxygen and nitrogen), are painted black and fitted with a right-handed thread. These two preventive measures would seem infallible against accident or oversight, and that nothing short of deliberate malice could render them futile. This disaster, however, showed how a little carelessness rendered both measures futile. For the brazing operations in question a cylinder of compressed coal gas was being used. It was painted the right colour, but the men using it found the thread of the nozzle did not correspond to this colour, and, instead of becoming mistrustful and putting the cylinder aside for enquiry as to its contents, they proceeded to fit a screw adaptor to make the necessary connections and lighted the gas at the issuing jet. It was then noticed that the flame did not burn properly and that heat was travelling along some 30ft. of rubber tubing connecting the jet with the cylinder. This, and the defective flame, did apparently give rise to a feeling that something was wrong, but before its magnitude and nature could be realised, the cylinder burst with terrific violence and

disastrous results. While the use of the adaptor was unjustifiable, it did not in itself explain why the cylinder burst, or the flame travelled back through the connecting pipe, for coal gas in itself is not explosive—that is to say, a jet escaping under pressure into the atmosphere simply burns with a flame, just as it does when it escapes from the ordinary gas burner. The explanation, however, was made at the inquest by the manager of the British Oxygen Company, who said that the cylinder had originally been black and charged with oxygen at their works, but had been returned to their works coloured red for recharging, and that a residue of oxygen in the cylinder had then become mixed with a charge of coal gas and thus produced an explosive mixture which would "back-fire." The extremely violent explosion which occurred would, however, hardly have been accounted for had the oxygen content only been that of the cylinder at atmospheric pressure, as it would have been had the residue in the cylinder been blown off in accordance with their usual practice, and he suggested that there may have been a blockage in the stop cock which prevented its escape, and in this way a considerable quantity of oxygen was mingled with the charge of coal gas when the cylinder was sent out again. To what extent this was the case it was impossible after the accident to say. The suggestion offered certainly would account for the explosion, though, in view of the precautions as regards colour and character of thread, it would seem a waste of gas to blow off residue merely to re-recharge a cylinder with the same constituent. At least we think it would seem so to the average workman, and that a breach of the salutary rule regarding blowing off might easily occur. Apart from this, however, the fact remains that the thread on the cylinder did not agree with the colour of cylinder, and it seems remarkable this discordance was not discovered by the British Oxygen Company in the first instance, for they, more than anyone, would know the importance of colour and screw thread relationships being strictly maintained to prevent risk of explosion. While, therefore, the workmen on the ship were guilty of negligence in using a screw adaptor to the cylinder, the company who supplied it cannot be absolved from blame, and this was evidently the opinion of the jury, for they returned a verdict to the effect that "the explosion was due to the cylinder being sent out filled with a mixture of coal gas and oxygen, and was contributed to by the servants of the Cunard Company in making an adaptor and disregarding the right-hand thread of the cylinder." We doubt not the lesson of the disaster will be taken to heart by the parties immediately concerned, and it is to be hoped also it will not be lost on others who may at any time be using cylinders of compressed gas. No cylinder should be used if colour and thread do not correspond, and the colour should never be tampered with. According to the evidence of the Oxygen Company, however, this is occasionally done, cylinders being returned to them painted red over black and vice versâ. In charity we must assume this occurs through carelessness or ignorance. These traits are the most frequent causes of accidents, and, as this disaster proves, are difficult to guard against. It remains only to ask whether existing precautions can be strengthened. It was suggested that the Oxygen Company should check the numbers on the bottles before they were recharged to ascertain their previous contents, but, as the managing director pointed out, even this would be no certainty against mistakes, and that a better plan—with which we agree—would be to make a difference in the diameter of the valve connections, though, as he added, this is of no avail "if men deliberately make an adaptor." The human element, with its liability to err, remains in any case. All one can do is to limit its play, and, with this object, we would urge that both suggestions be adopted.

Prevention of Shaft and Belting Accidents.

A REPORT on fencing and safety precautions for shafts, belts, wheels, pulleys, and other devices for transmitting power in factories by Mr. W. Sydney Smith, H.M. Inspector for dangerous trades, just issued by the Home Office, is of importance not only to factory owners, on account of the new regulations respecting such machinery which it is proposed to incorporate in the Factory and Workshop Acts, but also to those engineers who will as a consequence be called upon to make necessary alterations, or modify to some extent future designs. As an aid to this the report is accompanied with illustrations and explanatory notes which we think will interest others of our readers, and for this reason we reproduce them in another portion of this issue. The enquiry leading up to the report has been the outcome of the statistics relating to transmission machinery accidents over a number of years, and the comparison of which shows that "notwithstanding the constant development of electrical installations, improved methods of construction and arrangement of transmission machinery, and the requirements of the Factory Acts as to fencing, &c. . . . practically no decrease has occurred in the number of fatalities during the past six years (1907-12), while the decrease is only slight in non-fatal cases." The same type of accidents, the report points out, recur year after year, "due chiefly to workers coming into contact with mill gearing in motion when oiling bearings, adjusting belts, cleaning shafting, or performing other work in the vicinity of revolving shafts." The monotonous regularity of this casualty list is the more regrettable because it is so largely preventable. It is true also that workmen contribute by their own carelessness and recklessness to the injuries that fall upon them. This, however, applies to most machinery accidents, and the majority of fences and precautions are mainly designed to prevent the trespass or interference of persons who at the moment are either careless or off their guard. The primary danger from shafting is due to the motion of rotation. When clean and smooth there is nothing to indicate it, or even if it be observed nothing to suggest the enormous force it may be exerting, and to resist which a man's effort is futile should his clothing by any mischance become entangled. The danger of projecting studs is obvious, but the danger of the smooth shaft is too often overlooked, although it is little less, and as a source of accident is more serious. The figures for the year 1908 show that out of 331 shaft accidents reported, 44 of which were fatal, no less than 56 per cent. were due to articles of clothing becoming entangled, while in 1909 the proportion was 60 per cent. Even loose hair may be a source of serious danger near a revolving shaft, owing to the cyclonic air currents set up in the vicinity, and if it once becomes entangled nothing less than a horrible scalping is the price of release. In 1908 no less than 31 females were injured in this way. The danger from loose clothing becoming entangled is so obvious from the list of reported accidents, and so difficult to impress upon workpeople, that we are not surprised the Home Office propose to make enclosure of revolving shafting when it is within reach much more generally compulsory, and further to prohibit its cleaning when in motion by cotton waste or rags held in the hand. Even slow-running shafts may be a source of danger, and many accidents have been recorded in connection with shafts running at speeds of less than 20 revs. per minute. Apart from accidents due to shafts alone, probably the most dangerous work in connection with transmission machinery is the adjustment of belts. None but men more or less skilled, as a rule, undertake this, and many are remarkably dexterous. The reports, however, illustrate the risk run even by experienced men, as is evident

when we state that over 25 per cent. of the total number of shaft accidents and no less than 35 per cent. of the fatalities in 1908-9 arose in connection with the adjustment and repair of belting. The report, which we are giving elsewhere, illustrates a number of simple and ingenious devices for shifting belts into position that have from time to time been devised, and which seem to be more generally used on the Continent than here, where plain poles or hand manipulation are too often resorted to, and too often the source of accident. With the compulsory adoption of these and other safety devices indicated in Mr. Smith's admirable report, we doubt not that the present regrettable annual list of casualties will be greatly diminished.

A COMBINED MULTITUBULAR AND WATER-TUBE BOILER.

WE illustrate herewith a novel design of boiler, comprising a combination of the cylindrical multitubular and water-tube types. This design is the invention of Mr. J. B. Prudhon, and is manufactured by Messrs. Prudhon, Capus, Durand, and Co., Marseilles, the consulting engineers and agents in this country being Messrs. Douglas & Adair, 1, Fenchurch Avenue, London, E.C. The general arrangement of the boiler will be evident from a perusal of the illustrations. The water-tube boiler is arranged at the back end, and comprises water and steam drums, which are in free communication with the interior of the cylindrical boiler at the bottom and at the normal water level, respectively. The water tubes connecting the drums form side walls in the combustion chamber. Walls of firebrick are arranged between the tubes, as shown, to separate the combustion chambers of the furnaces, and also at the back end. Soot doors are provided, and the tubes can be cleaned by means of a steam jet. The method of attaching the steam and water drums to the end plate is shown in Fig 2. Flanged holes are formed in the end plate, into which the drums are expanded and riveted. In the case of the steam drums which project into the water and steam space in the cylindrical boiler, the ends are attached to a forked-piece, to which is secured by bolts in eye pieces the stays extending to the front plate of the boiler, thus allowing for expansion and contraction.

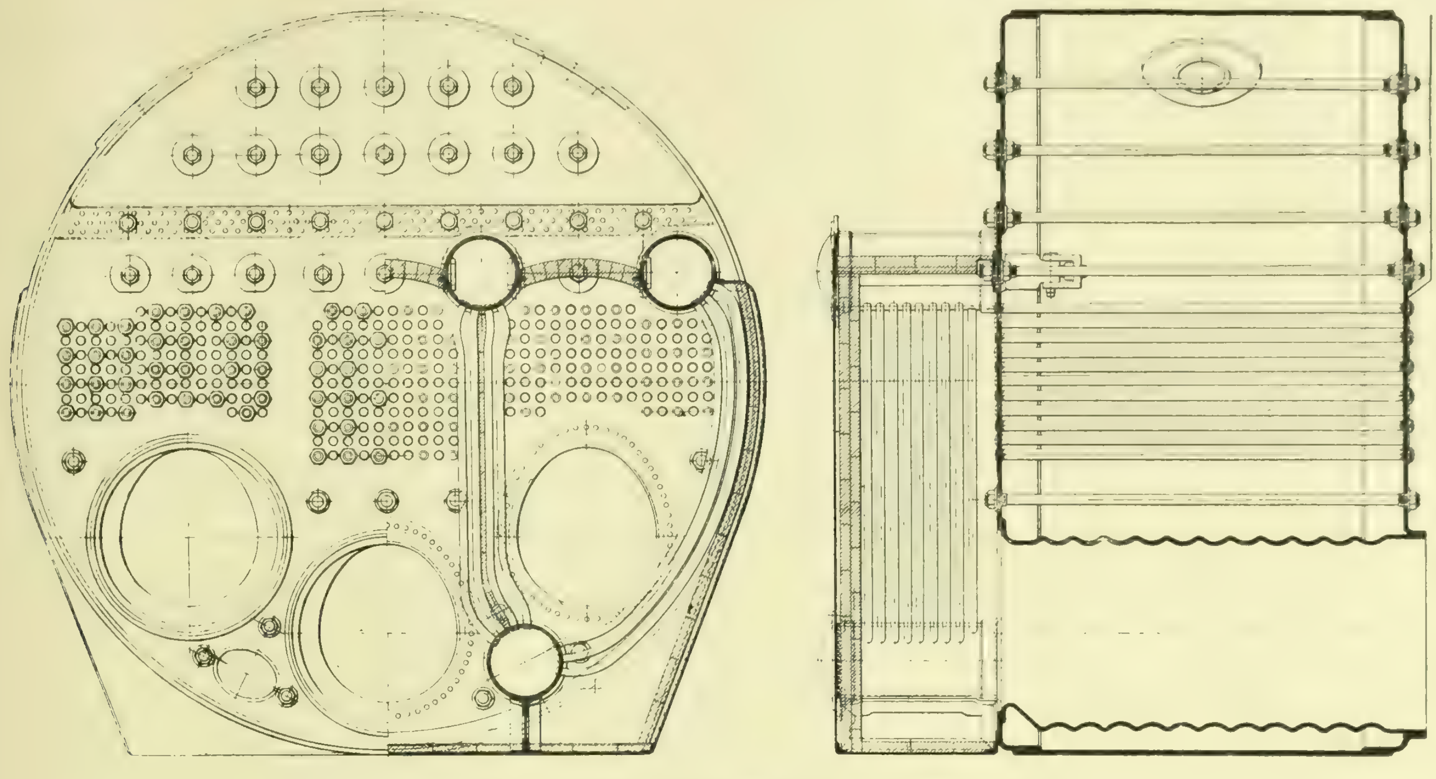


FIG. 1.—PRUDHON COMBINED MULTITUBULAR AND WATER-TUBE BOILER.

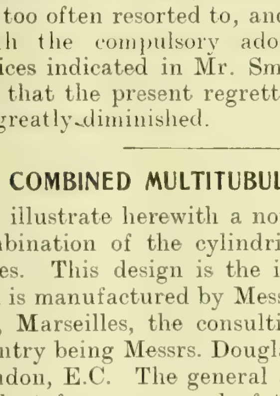


FIG. 2. METHOD OF ATTACHING STEAM AND WATER DRUMS. PRUDHON BOILER.

Boilers of this type have been fitted into a number of vessels, and are, according to the makers, giving excellent results. An installation of five large boilers, each with 2,960 sq. ft. of heating surface, were fitted into the "Germania," of 9,000 tons, belonging to the Fabre Line. These boilers replaced six ordinary cylindrical boilers of the same diameter, and the accompanying table gives the makers' comparison of the sizes and weights of the two types. The table also includes particulars of the Prudhon boilers which the same owners have ordered for the new steamship "Patria," of 15,000 tons. This installation comprises nine boilers, each having 2,540·3 sq. ft. of heating surface, of which 516·6 sq. ft. are provided by the water tubes, while the grate area is 65·5 sq. ft. In addition to these vessels there is being built another vessel of 15,000 tons, to be fitted with nine Prudhon boilers, by the Forges et Chantiers de la Mediterranée for the Société Commercaile et d'Affrétements.

	Ordinary Boilers for "Germania."	Prudhon Boilers for "Germania."	Prudhon Boilers for "Patria."
Number of boilers	6	5	9
Length of each	10ft. 10in.	12ft. 4in.	11ft. 11in.
Diameter of each	15ft. 7in.	15ft. 7in.	15ft. 11in.
Total heating surface in all boilers, including— Flame-tube surface. Water-tube surface. Combustion - chamber surface	15,823 sq. ft.	14,747 sq. ft.	22,836 sq. ft.
Total grate area	482 sq. ft.	325 sq. ft.	590 sq. ft.
Total weight of boilers, including fittings	330 tons	270 tons	486 tons.
Total space occupied by boilers	45,417 cub. ft.	40,402 cub. ft.	95,178 cub. ft.
Evaporative output of all boilers per hour	78,240lbs.	99,670lbs.	154,525lbs.
Pounds of water evaporated per pound of coal	8lbs.	9·52lbs.	9·52lbs.

ARRANGING TOOLS IN ACCORDANCE WITH SEQUENCE OF OPERATIONS.*

BY OSCAR C. BORNHOLT.

In any manufacturing enterprise the cost of production is very important, and a great deal of money can be wasted if proper facilities are not provided. Even though a plant has the very latest and most efficient machines and fixtures, money can be unnecessarily spent in trucking. Trucking in the machine shop is always looked upon as an unnecessary expense and yet many plants have a large trucking expense. This involves the question whether the manufacturing machines in a machine shop should be laid out in accordance with the sequence of operation, or whether they should be grouped according to the class of operation requiring like machines, such as placing together all milling machines, all drill presses, &c.

I will endeavour to show that the arranging of machines according to sequence of operation, as practised by the Ford Motor Company, has a great advantage over the classified machine grouping. In the former case the operations on any part to be manufactured can be outlined according to the best advantage in manufacturing the part. It might be well, on account of the nature of the part to be manufactured, to have a milling operation first, then drilling, then milling, and it would not make any difference what sort of machine followed on each operation. But if the latter arrangement of grouping were decided upon, the operations would have to

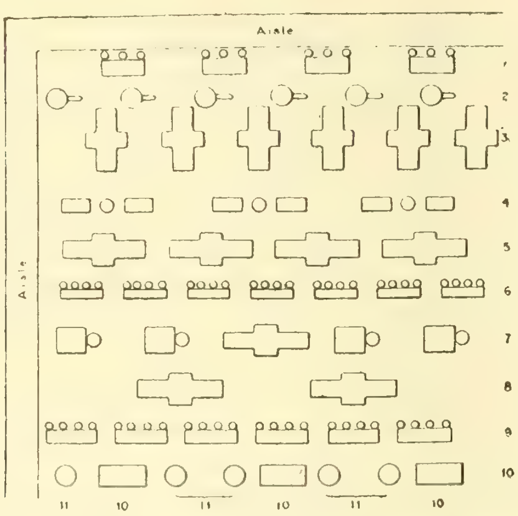


Fig. 1.—Sequence Arrangement of Machines in Cylinder Department. Ford Motor Company.

be arranged so that like operations on the same part would follow each other. For illustration, a milling operation should not come between two drilling operations, so that the part would have to be trucked to the drill department first, then to the milling department, and then back to the drill department. Trucking is expensive and all its labour is non-productive.

The trucking item is immense in a large plant when the machines are arranged according to class, as all parts have to be trucked many times before they are finished. When machines are placed according to sequence of operation there is no trucking of parts after the first operation is started, as each operator lays the part down in such a place and manner as to allow the next operator to pick it up and perform his operation, and so on. When finished, the part goes either to the finished stock room or assembling department.

A good example of continuous manufacturing is found in the making of tin cans. The body of the can is started at one side of the building in a machine for forming it; it next goes to the body-soldering machine and then to the header which has been fed with the two heads; when the heads are on, the can travels upstairs to have the heads soldered. The first machine sets the pace and the operators of the other machines must keep their machines moving at a similar rate so that the stock will not run short or accumulate. This arrangement therefore helps to increase production.

At the Ford plant the machines are arranged very much like the tin-can machines. All parts of a unit assembly are made on machines that are so laid out that the last operations bring them near together. This applies, of course, only to the large pieces, but all parts of a unit are made in one department under a foreman. Automatic screw machine parts are made in an automatic screw machine department where one man runs several machines. There would be no object or advantage in placing automatic machines among semi-automatic and manual operative machines. It is well understood that there are many operations that require more than one machine, but they are placed to draw from the one machine doing the previous operation. This gives the effect of the whole operation being done on one machine.

The operations have to be gone over carefully to ascertain the capacity either by previous records or by good judgment. In many operations more than one machine will be required, but there will not be work enough for two. Although the first cost may seem high it is a great saving to have a machine for every operation and enough of them.

The carbonising and hardening operations are awkward to have in the machine shop, but at the Ford plant a cyaniding and hardening department is placed in the middle of the machine shop. It is glassed in and thoroughly ventilated with a separate system to carry off the fumes from the cyanide pots. All parts to be cyanided and hardened are led up to this department and thus trucking to a separately located building is avoided. This would amount to several hundred tons of material a day.

On account of the great amount of heat generated, the heat-treating and carbonising departments had to be placed in a separate building where the walls could be opened 60 per cent. Brazing is done in the machine shop, just before the parts reach the assembling department. All shop furnaces are operated with low-pressure air ($1\frac{1}{2}$lbs.) and city gas.

As an illustration of unit production, I will take the universal joint which has only four pieces and four rivets. Assuming a production of 80 pieces per hour is required, it would take

80 universal joint knuckles (male),
80 universal joint knuckles (female),
160 universal joint knuckle rings (halves),
320 rivets.

The universal joint knuckle (male) has six operations, as given in Table 1.

Table 1.—*Operations on the Universal Joint Knuckle.*

Operation.	Work.	Machines Required.	Capacity, per Hour.
First	Mill square end	2 Millers	40
Second ..	Turn to size, $3\frac{1}{8}$in. diam...	1 Lathe	80
Third	Turn trunnion ends	2 Duplex drills	40
Fourth ..	Mill ends, shoulder clearances.	2 Millers	60
Fifth	File	Bench for filing	
Sixth	Harden	Furnace in the hardening-room in the machine shop; knuckle to be returned to assemble.	–

The operations on the universal joint knuckle (female) are similar. The rings are broached, and then ground on a disc grinder, which is placed in the machine shop. The grinder is equipped with a dust exhauster and collector so that no emery dust flies to other machines. After all the parts are completed, they are led up to an assembler who also rivets them. They are then inspected and sent to the finished stock room or the assembling department, usually the latter, since the production of the whole shop must be balanced up.

At the Ford plant, the cylinders are trucked from the foundry to the border of the aisle, down which are located the machines which perform the first operation. They are light enough to be carried by the operators to their machines

* Abstract of paper read before the American Society of Mechanical Engineers.

while the latter are making cuts. The cylinders move to each successive machine until they land in the assembling department which borders the cylinder department. All cast-iron parts are made in the same way; some of the small parts have to be trucked to the assembling department, but in rare cases only. The trucking that is done at the Ford plant is taken care of by many two-ton monorail travelling hoists operated by electricity and forming a small railway system. An illustration of the cylinder department for the first few operations is given in Fig. 1.

First operation—drill, tap, and plug three-cored holes.

Second operation—spot face and inspect. This is one of the most important operations on the cylinder, since it detects any defect that might have occurred in the foundry. It also finishes spots to enable the placing of the cylinder in the jigs quickly and accurately. Many cylinders are thus saved in this jig because it is arranged to adjust the cylinder to ensure its being finished all over.

Third operation—mill bottom.

Fourth operation—drill six main bearing bolt holes and ream two of the holes for use in gaging or jigging. The drilling is done in a six-spindle inverted drill press and the two holes are reamed in a single-spindle drill press.

Fifth operation—mill top and sides.

Sixth operation—bore cylinder barrel.

Seventh operation—water test.

Eighth operation—mill ends of cylinder.

Ninth operation—finish ream barrel.

Tenth operation—drill valve seat holes.

Eleventh operation—drill and ream valve-stem holes, &c., until the cylinder reaches the assembling department.

It may be of interest to compare the two ways of arranging machines for manufacturing by using the cylinder operations of various kinds. In placing the machines according to operations it is necessary only to truck the cylinder to the first operation and after the last, because it is quite necessary to stock a few cylinders ahead of assembling. If the cylinders were to be machined in departments consisting of like machines, it would be necessary to truck to and from each department. Considering 1,000 cylinders a day and the cylinders weighing above 80lbs. each, it would total 80,000lbs. to each department.

Grouping the operations on the cylinder to see how many times it is handled in how many departments, there are: Drilling, milling, lathe, testing, tapping, babbiting, back to drilling, and grinding. It would be conservative to estimate that the cylinder would have to be trucked about 12 times. On account of some operations it would have to return to a department in which it had already been, and would therefore be handled more times than there are departments.

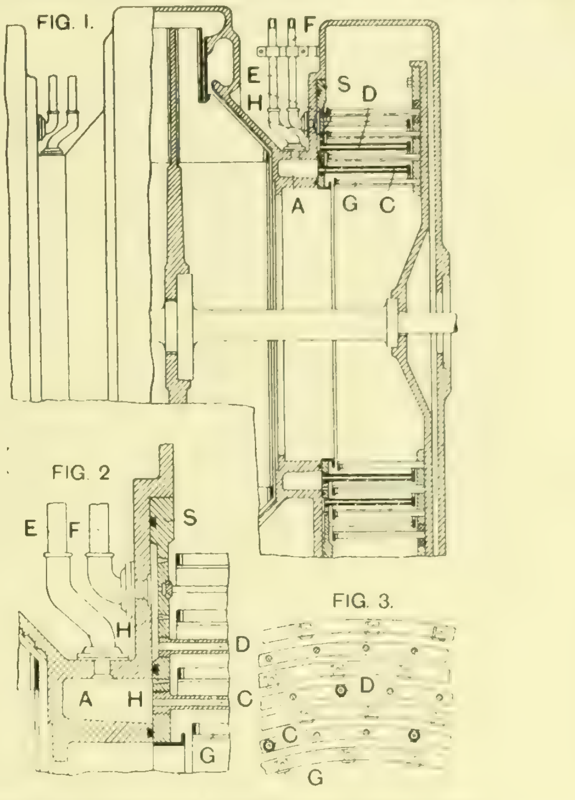
Each handling will amount to 80,000lbs., or 40 tons, and 12 handlings will amount to 480 tons a day, while the total number of feet of movement for each cylinder will be at least 500. This makes 480 tons travelling 500ft. at the probable rate of 180ft. a minute, which is about the gait of a man trucking. Assuming a man can truck 960lbs. or 12 cylinders, at the above rate of travel, and figuring the necessary time for loading and unloading as 10 minutes, it would require a force of 24 men with trucks to handle the 1,000 cylinders per 10 hours.

While it may be claimed that the cylinder is especially adaptable to manufacture with machines placed in accordance with the sequence of operations, small forgings can also be produced in quantities much cheaper in the machine shop when the machines are placed in this way.

There is another advantage in placing the machines in accordance with the sequence of operations: even though some machines are not worked to their full capacity the amount invested in them is well paid for from the fact that it is not necessary to carry nearly so much stock as when the machines are grouped according to their classification. Each group or department alone would in that case need to have nearly as much raw stock to work with as is necessary with this method to operate the whole series of machines to complete the part.

THIESEN'S APPARATUS FOR WASHING, PURIFYING, AND COOLING GASES.

The atomising apparatus for purifying, cooling, and mixing gases, shown in the accompanying illustrations, has been designed and patented by Mr. H. E. Thiesen, 34, Elisabeth strasse, Munich, Germany. The water injection pipe C and D are fixed, while the disintegrator bars G rotate. The gas is made to pass radially through the atomised liquid. The injection pipes C are arranged on the annular disc S which covers a passage A supplied with water through pipe E. The injection pipes D which introduce the water into the outer layers are also arranged in the annular disc S between the atomising bars as shown in Fig. 3, in such a way that the water injection pipes D alternate with a larger number of bars. The water to the pipes D is introduced by means of a separate pipe F, so that by shutting off and turning on the pipe E or the pipe F the mixture with water may be suitably regulated. The water injection pipes are so arranged on the annular discs S that they may be easily removed and cleaned when necessary. The water introduced through the injection pipes C is prevented from being carried over into the fan by



Thiesen's Apparatus for Purifying and Cooling Gases.

means of the rotating ring of bars or angle irons G arranged inside the injection pipes C in such a way that should any water be carried inwards it will be thrown outwards again.

In experiments with atomising washers it has been found that the washing water is not sufficiently intensely distributed over the side walls of the rotating atomising apparatus. Further both in the case of atomisers having partly fixed and partly rotating atomising surfaces, and also in the case of atomisers having atomising devices which rotate in opposite directions, it has been found than an annular space is formed through which unwashed gas can pass radially, at the free end of the atomising device close to the disc S. In order to prevent this radial escape of gas along the disc S the water is not only introduced through the pipes C and D but also further from the side, so that the radially escaping gas is diverted axially and again introduced into the atomising device. An intense flushing of the side walls thus takes place, and by the impact of these laterally introduced water jets on the atomising device, the water is atomised and thoroughly mixed with the gases. The passage of unpurified gas through the annular interval along the annular disc S is thus entirely excluded and the deposition of tar and dust and the formation of incrustations is also avoided. The water is introduced laterally through apertures H in the annular disc S, as shown in Fig. 2.

FENCING AND OTHER SAFETY PRECAUTIONS FOR TRANSMISSION MACHINERY.*

Shafting.—It is a dangerous fallacy to assume, as is often done, that slow-running shafts, or shafts of large diameter, are free from danger and need not be safeguarded. Every shaft is required by the Factory Acts to be securely fenced, irrespectively of its speed or size, unless it is equally safe by position or construction as if it were fenced. Unfenced smooth shafting of 12in. diam. and shafts running at less than 20 revs. per minute have been responsible for fatalities. It is essential to prevent accidental or unintentional contact with any revolving shafting. The following rules should apply to horizontal, vertical, and oblique shafts: (1) Shafts less than 6½ft. above the floor level should be securely fenced. (2)

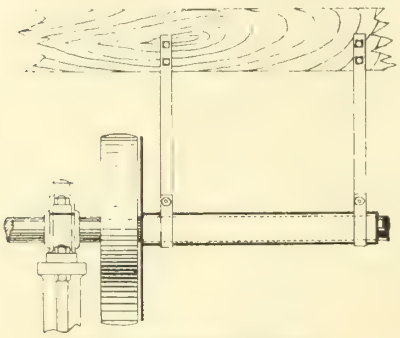


Fig. 1.—Sheet Metal Tube.

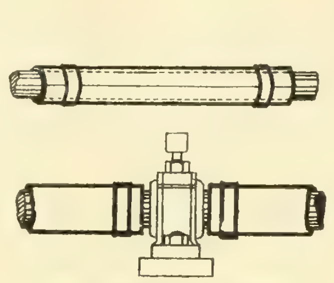


Fig. 2.—Millboard Tubes.

Shafts more than 6½ft. above the floor level to be securely fenced which are less than 6½ft. from any point to which workers may need occasional access for such purposes as lubrication, cleaning, manipulating belts, or other work of maintenance of transmission machinery; or any occasional work other than the work of maintenance of transmission machinery; except where the shaft is stopped at the time any worker approaches within 6½ft. of it; or the shaft is moving at less than 6 revs. per minute at the time any worker approaches the transmission machinery for the purpose of adjusting belts, and due provision is made (by signals or otherwise) for prompt stoppage at the first sign of danger.

The type of fencing needed varies with the position and arrangement of the transmission machinery, but shafts are usually fenced either by complete or partial casings, consisting of fixed or loose sleeves, or by guard rails so placed as to prevent access. Tubes of sheet metal or millboard (Figs. 1 and 2), sheet-metal troughs (Fig. 3), and wood casings (Fig. 4), make excellent guards. These may be attached by suitable brackets to such supports as pedestal bearings,

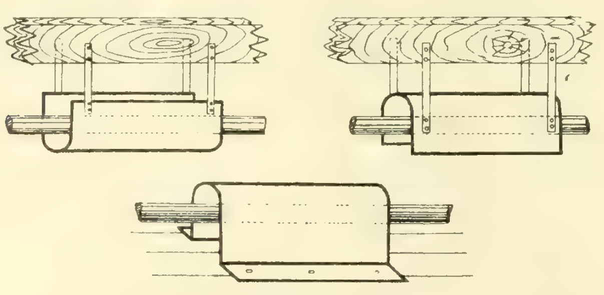


Fig. 3. Sheet Metal Troughs.

hangers, wall boxes, overhead beams, walls or flooring. Wire netting is sometimes similarly used but is less cleanly than complete casings of sheet metal or wood. Millboard tubing somewhat larger in diameter than the shafting may be slipped over the shaft as a loose sleeve which will revolve when the shaft is in motion, but will stop immediately if a person comes in contact with it. Millboard tubes are made of varying lengths, in halves or split on one side. The parts can be readily fastened together by means of thin wire or metal clips which should be free from projections. Loose metal sleeves are often similarly used for fencing shafting and projecting shaft ends. When shafting is fenced with partial casings, care should be taken that the revolving shaft is covered sufficiently by the casing. Many accidents have occurred on shafts protected on two or three sides leaving the shaft exposed in one or more positions. Shallow partial fencing, such as a trough or single board placed under, over, or adjacent to shafting, is dangerous. For this reason, complete casings are preferable to partial guards unless deep troughs of wood or metal are used.

In some instances, owing to the number of pulleys upon low lines of shafting, the shafts cannot be encased. Guard rails are then necessary. The rails should not be too wide apart and the space between shaft and rails, whenever the diameters of the pulleys or the positions of the driving belts permit, should be about 12in.; if it exceeds this distance a person may enter within the space, and if less than this accidents may happen through contact with the shaft by

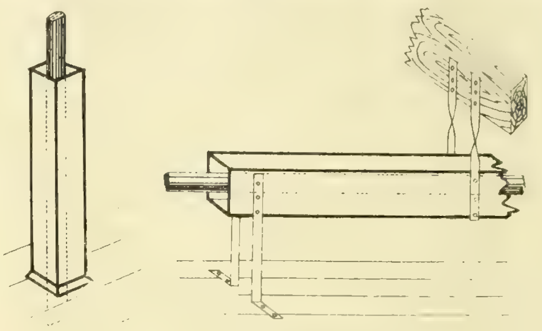


Fig. 4. Wood Casings.

clothing or materials, or by persons falling against the rails. Rails should be sufficiently strong to resist bending if used as foot rests. Care is also necessary as to position of the guards and spacing of rails and boards to allow, with safety, the adjustment of driving bands and the necessary cleaning under benches, but at the same time to avoid the possibility of the hair being caught. A space of eight inches between the floor and lowest guard, with spaces not exceeding six inches between the higher rails or boards, will not interfere with cleaning or manipulation of belts and will almost entirely remove the risk of accident. In general, where females

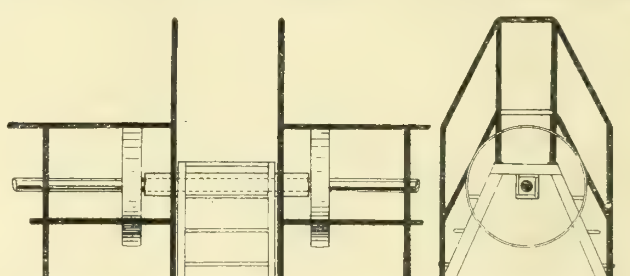


Fig. 5. Fencing for Low Shafting, with Steps over Shaft and Handrails.

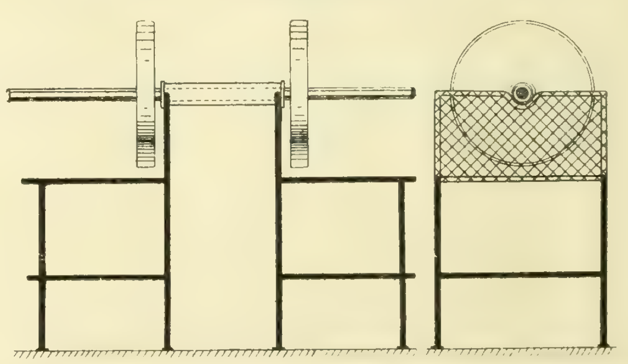


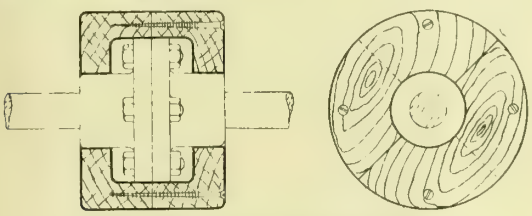
Fig. 6. Fencing for Shafting with Fenced Passage-way under Shaft.

are employed, greater care is needed as to the fencing of transmission machinery in order to avoid accidental contact of the worker's hair or clothing with revolving parts; complete encasing of shafting, with protection of pulleys by side plates, as shown in Fig. 1, is preferable.

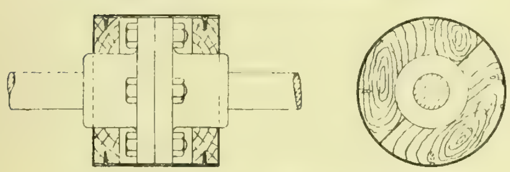
Whenever it is necessary to cross low lines of shafting fenced by rails, there should be gangways or steps at suitable intervals so as to fence the shaft, with handrails on either

* From Home Office report on "Fencing and Safety Precautions for Transmission Machinery," by W. Sydney Smith, H.M. Inspector for Dangerous Trades.

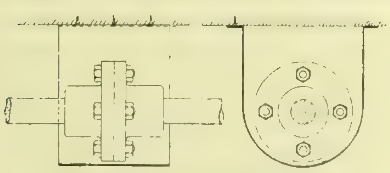
side of these crossing places (Fig. 5). Where the shafting is high enough to allow passage underneath, but less than 6½ft. from the floor level, the shaft should be completely encased at the passage ways (Fig. 6). High shafting in motion must be approached from time to time by engineers, greasers, beltmen and other persons employed in oiling, cleaning, adjusting belts and similar work of maintenance. Where space permits there should be an overhead gangway or service platform, sufficiently near the shafting to admit of the necessary work being done in safety and yet at such a distance as to prevent contact with transmission machinery in motion. The platform should have guard rails to a height of three feet and a skirting board to prevent the worker falling under the rails or fall of tools on persons below. Failing overhead gangways, the approach may be made by a safe type of ladder, but in such cases there is always risk of accident unless the shafting in the vicinity is fenced, stopped, or considerably reduced in speed. High shafts are often permanently encased for about two feet on either side of each bearing, the casings being fixed by suitable brackets to the bearings or hangers. Ladders are sometimes provided with an inverted trough which rests on the shaft and so fences the portion temporarily, these may be used where there is ample space between pulleys, couplings, and bearings. If there be lubricators, or self-



Wood Discs in halves screwed together.



Sheet Metal Band screwed to wood discs.

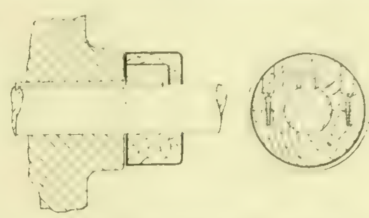


Sheet Metal Band screwed to ceiling.

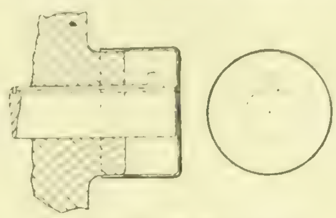
FIG. 7.—FENCING FOR PROJECTING COUPLING BOLTS.

lubricating bearings, oiling can generally be done at rest, but replacing of belt on pulleys is impossible in many cases unless the shafting and pulleys are moving. With various types of belt mounters this operation can be done in safety from the floor level, at the ordinary working speed of the shafting. Where pulleys are close together, fencing of the shaft is often impracticable and if the worker approaches unfenced transmission machinery in motion to adjust belts, in addition to contact with the revolving shaft, there is always the danger of contact between belt and pulley, or belt and shaft. Hence, in cases where approach to unfenced shafting is necessary, it is imperative that the speed of the shafting be previously reduced to a safe limit. Severe accidents have occurred on shafting moving at only 9 revs. per minute, and a fatal accident on a shaft moving at only 5½ revs. per minute; but a speed not exceeding 6 revs. per minute may be considered safe for the dangerous operations of manipulating belts by hand on transmission machinery in motion, provided due provision is made by signals or otherwise for prompt stoppage at the first sign of danger.

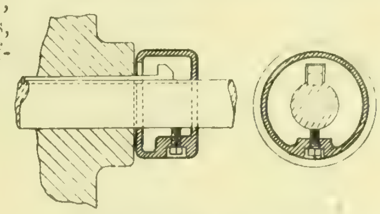
Couplings.—Projecting bolt heads, nuts, screws, and keys should be prohibited in all new installations of transmission machinery. Shaft couplings should be constructed with countersunk bolts and nuts, shrouded flanges, or other equally safe devices. In existing installations, as shaft couplings are generally situated near the bearings, all projections should be covered by smooth wood or metal casings if the shafting is ever approached whilst in motion. Various methods of fencing projecting coupling bolts are shown in Fig 7. The wood discs are made in halves to enable them to be fixed on existing shafts. Projecting keys of couplings, wheels, and pulleys should be covered with wood or metal caps if these portions of the transmission machinery are ever approached in motion. An exception, however, must be made for keys (feather or sliding keys) used in connection with sliding portions of the transmission machinery, such as clutches and sliding wheels. For new installations the caps may be made in one piece and slipped in position on the shaft before erection. For shafting already in position the caps must be made in halves.



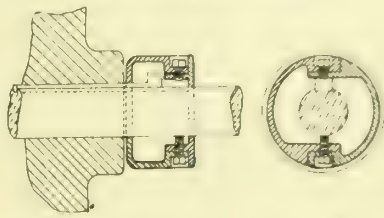
Wood Cap in halves screwed together.



Sheet Metal Cap on pulley boss.



Cast-iron Cap with countersunk set-screw.



Cast-iron Cap in halves secured with countersunk set-screws.

FIG. 8. GUARDS FOR PROJECTING KEY HEADS.

For projecting keys near shaft ends, circular sleeves may be driven on the boss of the coupling or pulley. Different types are shown in Fig. 8.

Collars.—Projecting set-screws on shaft collars should be prohibited on all new installations. Countersunk set-screws or other equally safe method of attachment should be provided. On existing installations of transmission machinery, as collars are always situated in close proximity to bearings and loose pulleys, projecting set-screws should be removed, replaced by countersunk set-screws, or covered with a smooth cap or guard if the shafting is ever approached whilst in motion. See Figs. 9 and 10 for types of guards.

Wheels, Drums, and Pulleys.—All appliances of this nature if less than 6½ft. from the floor level or any place to which the workers have occasional access, should be fenced so securely as to prevent accidental contact by persons with parts in motion, but appointed persons such as enginemen, oilers, and beltmen may be allowed to approach unfenced drums and pulleys for the necessary work of manipulating driving belts and ropes at times when the speed of the shafting and pulleys does not exceed 6 revs. per minute if adequate provision is made for prompt stoppage of such parts at the first sign of danger. Gear wheels, if situated as above, should be encased with metal guards fully protecting the teeth and rims with a portion of the guard hinged or sliding to facilitate lubrication of the teeth. Partial guards for gear wheels are always inadequate and may even be dangerous; though the ingathering teeth may be protected, additional points of danger are introduced between the teeth and the ends of the guard, and fingers, clothing, or cleaning rags may easily be caught unless the teeth are wholly covered. Complete guards, enclosing the whole of the wheels, have the advantage of preventing access of dust and also limit the splashing of grease. For these reasons gear wheels on overhead line shafting are generally completely fenced. Sprocket wheels for chain drives should be fenced like gear wheels, if similarly accessible. Friction gearing is equally dangerous as toothed gearing at the intaking parts, but guard rails are generally sufficient for

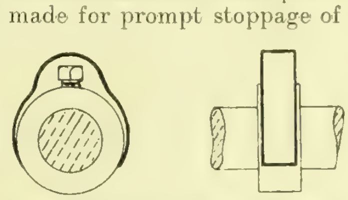


FIG. 9. STEEL-CLIP GUARD FOR PROJECTING SET-SCREW OF SHAFT COLLAR.

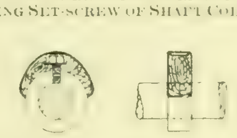


FIG. 10. WOOD GUARD FOR PROJECTING SET-SCREW OF SHAFT COLLAR.

this type of transmission machinery if the fence is maintained in such position that the space between rails and dangerous parts cannot be entered by the workers.

The type of fencing for drums and pulleys is often determined by their position and the direction of the driving bands and ropes; the guards may generally be so arranged as to include fencing for both pulleys and bands (Fig. 11). Fast pulleys near the floor level are dangerous owing to the risk of clothing and feet becoming entangled between belt and pulley. These should be protected by guards which should also fence the loose pulleys and driving belts. Fenders of wood or metal form satisfactory fences for pulleys in such positions. Guard rails are often so used; sheet metal, wire netting or perforated metal being added according to special circumstances where the pulleys are more exposed or greater danger exists owing to the employment of females. Overhead pulleys within reach of the workers should be fenced underneath (Fig. 12) with strong guards of metal or wood, which should be extended to protect the low-lying portions of horizontal and oblique driving bands in order to prevent accidental contact with moving parts and especially at the intake between belt and pulley which is the most dangerous part. Accidents are often due to contact with the spokes of pulleys and wheels in motion. Hence the sides of spoked pulleys within reach of workers or to which they may have access should either be fenced or the spokes filled in with circular discs to convert them into plate wheels. The sides of all drums in the grinding rooms of tenement factories are required to be closely fenced and the need is the same wherever spoked pulleys are accessible to the workers.

Belts, Ropes, and Chains.—As regards the fencing of belts other considerations arise, and the conditions are materially different from those of shafts and pulleys. Heavy overhead belts which may never be approached whilst in motion, and are to that extent safe by position, often require to be protected underneath as a safeguard in case of breakage; further, the fencing of the low belts driving the individual machines, *e.g.*, looms, lathes, and other machine tools, is in many cases impracticable, and though such belts are strictly mill-gearing, little danger arises where metal fastenings are avoided and efficient strap-forks are provided.

Periodical examination of belts would lessen the number of breakages. Belt accidents would also be reduced by prohibiting the use of projecting metal fasteners or by requiring all belts with such fastenings to be fenced. There is, however, always risk of accident arising from contact at the intake between belt and pulley or contact with running belts, and fencing is necessary in the following circumstances: (1) All vertical and oblique belts (irrespectively of size and speed) passing through floors should be fenced round the openings by rails or casings of wood or metal to a height of at least 4ft. Where the belts

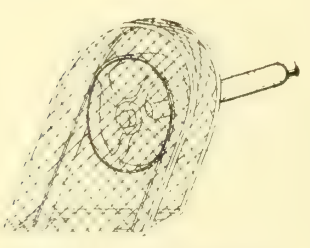


FIG. 11. GUARD FOR BELT AND PULLEY. (WIRE NETTING.)

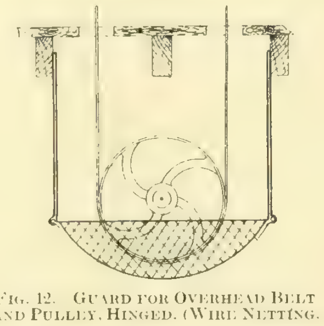


FIG. 12. GUARD FOR OVERHEAD BELT AND PULLEY. HINGED. (WIRE NETTING.)

are oblique it may also be necessary to fence the underside of the belt to a height of at least 6½ft. so as to prevent accidental contact. (2) Horizontal and oblique belts used for main driving and counter-driving within 6½ft. of the floor or other place to which the workers have access while the transmission machinery is in motion, should be securely fenced by rails or casings so as to prevent accidental contact (3) All overhead main driving belts, if more than 4in. wide and moving with a velocity of more than 30ft. per second, should be protected underneath with strong guards of wood or metal at those parts where persons are liable to pass under them.

The protection under heavy overhead belts must be substantial, *e.g.*, troughs of wood, sheet metal, perforated or expanded metal, strongly constructed and firmly supported by the walls or beams (Fig. 13). Ladder-like guards made of angle irons fitted with metal rungs (Fig. 14), or strong bow-shaped iron cleats fixed at intervals (Fig. 15) are also efficient; the latter types will not interfere with the examination of the belt or of a rope and have the advantage that the driving bands or ropes are always visible. Fencing of other driving belts, in addition to main-driving and counter-driving belts, may be necessary according to position, size, speed, or special circumstances, but much judgment and experience are necessary; low belts near the floor level and high-speed belts should in general be guarded, but each individual case must be considered on its merits as to the degree of danger and the nature of the fencing requisite under the circumstances. In connection with the latter point, minimum interference with manufacturing processes, efficiency as a guard, and access in case of repair or alteration have to be considered. Many belt fasteners are dangerous on

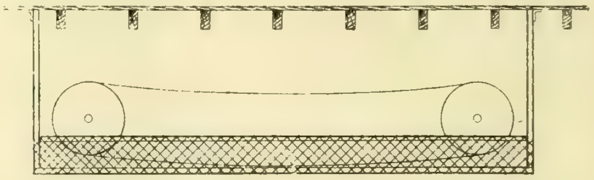


FIG. 13.—GUARD FOR OVERHEAD BELT. (EXPANDED METAL.)



FIG. 14.—GUARD FOR OVERHEAD BELT. (LADDER TYPE.)

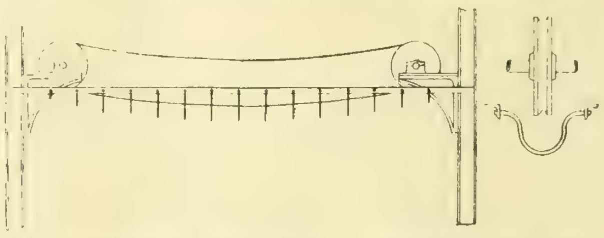


FIG. 15.—GUARD FOR OVERHEAD ROPE. (BOW-SHAPED IRON CLEATS.)

account of metal projections, but of metal fasteners those consisting of continuous wire stitching held together by a peg other than a metal peg are safe. Belts with other forms of metal fasteners within reach of the workers should always be fenced. Loose ends must not be allowed on belts, unless the belts are securely fenced.

The fencing of driving ropes, except overhead ropes, should generally be on the same lines as the fencing of belts. There is not the same need for fencing small overhead driving ropes, as ropes never break without showing signs of wear and giving ample warning before breakage by the production of quantities of fluff, unlike belts which generally break unexpectedly. Low sagging ropes above passage ways in engine houses, rope races and work places should, however, always be protected by strong troughs or other efficient guards.

Driving chains of metal, on account of their weight, are more dangerous than belts or ropes; the intake between a driving chain and pulley is as dangerous as the intake of toothed gearing. Chain belts should at least have a strong trough underneath, whatever their position, and if accessible they should be enclosed.

(To be continued.)

The Junior Institution of Engineers: North-western Section.—The members of this section of the Junior Institution of Engineers paid a visit on Friday evening, the 13th inst., to the Trafford Park Works of Messrs. Redpath, Brown, & Co., Ltd., structural steel work engineers. Mr. Cowan received the visitors and, assisted by members of his staff, showed many of the most up-to-date processes now used in structural engineering. Oxy-acetylene cutting excited great interest, steel joists 12in. by 7in. being cut through straight and clean in one minute. The layout of the various machines in the works was such as to facilitate expeditious and accurate machining.

COMPARATIVE TESTS OF LINESHAFT BEARINGS.

In a paper read at the recent annual meeting of the American Society of Mechanical Engineers, Prof. Carl C. Thomas, of the University of Wisconsin, gave the results of comparative tests on three types of lineshaft bearings. The shafts, which carried uniformly-distributed known loads, were supported successively by ring-oiled babbitt, roller, and ball bearings, the same number being used in each case. A wide range of loads and speeds was covered, and the coefficients of friction were worked out for each type of bearing. These tests, which were made at the university, extended over a period of four years, and all questions of possible lack of alignment, non-uniformity of loading, temperature and quality of lubricant, &c., were carefully considered. As a result of these tests it was found that the power required for babbitt bearings was higher than for the others, except perhaps at low loads and speeds, and that the power for roller bearings was higher than for the ball type. The excess of power required by babbitt over roller bearings and by the latter type over ball bearings increased with an increase of speed for all loads. The relative amount of power consumed in friction by the three kinds of bearing at speeds of 100ft. and 300ft. per minute, and temperatures of 77° and 100°, are given below. The relative numbers are based in each case on the average power for three loads of 710lbs., 1,210lbs., and 1,710lbs. for ball bearings, 740lbs., 1,240lbs., and 1,740lbs. for roller bearings, and 730lbs., 1,230lbs., and 1,730lbs. for babbitt bearings.

Relative Amounts of Power Consumed in Friction.

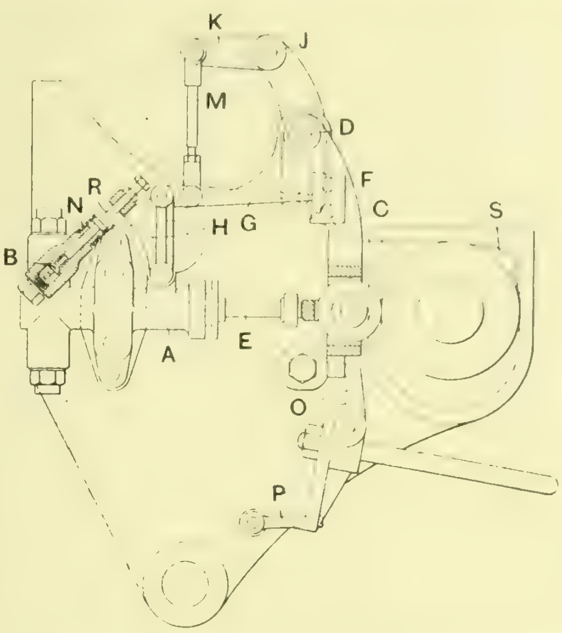
Bearings.	100ft. per minute.		300ft. per minute.	
	77 deg.	100 deg.	77 deg.	100 deg.
Ball	1	1	1	1
Roller	2·2	2·5	2·7	3
Babbitt	3	3·6	4·5	4

To observe the performance of the bearings under extraordinarily heavy loads, breakdown tests were run on each type of bearing with only one section of shafting, on which were four bearings. In this case a constant speed, 200 revs. per minute, was employed. Tests began at about 3,200lbs. per bearing, and failure occurred at about 4,250lbs. per bearing in the case of the babbitt bearings, 4,650lbs. for the ball bearings, and about 5,100lbs. in the case of the roller bearings. The bearings in any case did not fail structurally, as the power was cut off soon after distress was manifested, but the failure was simply that of the lubricant. Breaking down of the lubricant resulted in immediate increase of the power required to maintain the original speed of rotation of the shaft in the bearings. It is pointed out, as a result of this test, that the quality and the amount of lubricant used undoubtedly has an important effect upon the load that will cause a given bearing to fail.

FUEL VALVE ARRANGEMENTS FOR INTERNAL-COMBUSTION ENGINES.

We illustrate herewith an arrangement for operating the fuel-supply pump and for controlling the relief valve of internal-combustion engines of the type in which liquid fuel is supplied under pressure by a pump having a stroke of constant length to a spraying device and in which a relief valve controlled from the engine governor is provided on the pump delivery side, so as to allow of the escape of the pump delivery at any period during the pump stroke in order to vary the charge received by the engine.

The fuel pump A is of ordinary construction and delivers fuel to the engine spraying device, a relief valve B being provided upon the passage leading between pump and sprayer for releasing the fuel from the passage, under the controlling action of the engine governor, at any period in the pump stroke so as to vary the quantity of fuel delivered to the engine. The means for operating the pump A and the relief valve B comprises an arm C fulcrumed at D and rocked by a cam S. The arm engages the ram E of the fuel pump so as to reciprocate same. The stroke of the ram is maintained constant so that the pump deals with a fixed quantity of liquid fuel at each stroke. The arm C has also mounted thereon a striking plate F having its striking surface shaped to an arc of a circle, and this plate engages a striker arm G connected to a pivoted member H which actuates the spindle R of the relief valve B. As the arm carrying the striking plate F is rocked, the relief valve B may be actuated to release the fuel delivery by the pump. The striker arm G has its position controlled by the engine governor acting through the spindle J, arm K, and link M, the effect being to draw the end of G which engages the striking plate F away from or towards the fulcrum point D of the arm C, so as to vary the timing of, and also to increase or decrease the duration of the movement imparted to the relief valve B. In one extreme position of the striker arm G, the whole of the fuel pump delivery is released so that the engine does not receive any combustible charge, whilst in the other extreme position, the relief valve remains closed throughout the pump



Arrangement of Fuel Valves for Internal-combustion Engines.

delivery stroke. The intermediate positions of the striker arm provide for an earlier or later release according to the load requirements of the engine. A spring retains the relief valve normally in its closed position. This valve is set diagonally as shown, or vertically so as to assist in the discharge of any air past the valve which may pass over with the pump delivery. To provide for hand actuation of the arm C carrying the striking plate F and operating the fuel pump A, so as to work the latter by hand when starting the engine or when testing the pipe circuit or for similar purposes, a hand lever O is provided which engages the end of the arm C. It can be locked by means of a locking piece P in a position in which the arm C is free from the cam S by which it is normally rocked so as to stop the engine. The arrangement described has been designed and patented by Messrs. L. Gardner & Sons, Ltd., Patricroft, Manchester.

North of England Institute of Mining Engineers.—A general meeting of this Institute was held on Saturday last at Newcastle, Col. W. C. Blackett, president, in the chair. Papers were read by Mr. H. W. G. Halbaum on "The Automatic Distribution of Stone-dust by the Air Current"; by Mr. John Morris, "Notes on Gob-fires and Blackdamp, &c."; and by Mr. Leo. Dorey Ford on "A Westphalian By-product Coking Plant, which also supplies Town Gas." Mine signalling apparatus were exhibited, described, and demonstrated by Messrs. Mechan & Sons, Ltd., Messrs. Siemens Brothers and Co., Ltd., Messrs. Hugh Wood & Co., and the British Electrical and Manufacturing Company. A speed and volume recorder, a fan suction gauge, and an optical pyrometer were also exhibited, described, and demonstrated by the Leslie Company, Ltd.

CASE HARDENING.*

Two kinds of case carburisation may be distinguished: complete carburisation of metals or core carburisation; and case carburisation or case hardening of metal parts which must support considerable penetration stresses and at the same time must preserve as much of their malleability as possible. The author discusses the various theories of case carburisation and comes to the conclusion that carburising action must be ascribed practically exclusively to carboniferous gases, namely, to carbon monoxide. In this connection it becomes important to consider the value of gases given off by various kinds of carburisers in use, especially in view of the fact that an excessive evolution of such gases may cause explosions during carbonisation. De Nolly and Veyret have studied this problem and recommend the following precautions: (*a*) To avoid animal and vegetable matter giving off too much gas at low temperatures. (*b*) To use with barium carbonate (30 to 50 per cent.) only charcoal carbonised at a very high temperature. The evolution of gas is thus smaller and the percentage of hydrogen lower. (*c*) To heat the mass slowly up to 700° C. (1,292° Fah.); the air can then escape and the violent evolution of gases at a temperature around 700° C. is reduced. As regards possible weakness of the core of the carbonised part, nitrogen is only occasionally the cause, but hydrogen is far more dangerous in that it produces hard or brittle places consisting of pure ferrite.

The evolution of gases with different kinds of carburisers in use occurs approximately in the following manner: Pure charcoal at temperatures from 0° to 300° C. (32° to 572° Fah.) evolves gases which are absorbed by the charcoal itself. At 300° C. (572° Fah.) there is a minimum of gas generation. The air is driven off and the volatile gases are still occluded. From 300° to 700° C. (572° to 1,292° Fah.) the internal evolution of the gases takes place, and at 700° C. there is a maximum of evolution equal to about 30 times the volume of the charcoal. Beyond that temperature the evolution of the gases decreases. At 1,100° C. (2,012° Fah.) the contents of carbon monoxide increases a little. At the second heating the evolution of gas is very weak. The mixture of barium carbonate and charcoal calcined at 1,000° C. (1,832° Fah.) gives off practically no gases until 600° C. (1,112° Fah.), the evolution of the gases reaching its maximum toward 1,000° C. At 1,050° C. (1,922° Fah.) the gas contains 75 per cent. carbon monoxide and 12 per cent. hydrogen. Ferro-cyanide carburisers reach their maximum of evolution of gas at about 800° C. (1,472° Fah.), but very rapidly cease to give off gas.

Case carbonisation is therefore the result of the absorption by iron of the carbon left in the carburising material by the evolution of the gases, but in order that iron might absorb carbon, it must be in the allotropic state γ, since iron in the state α does not dissolve carbon, at least not constantly and in a useful manner. By heating iron in close contact with the carburiser above 700° C. (1,292° Fah.), or even up to 560° C. (1,040° Fah.), the beginning of carburisation is obtained. Giolitti and Carnevali have shown that steel with very low content of carbon is not carburised at all below 780° C. (1,436° Fah.), and they explain facts to the contrary mentioned above by supposing that carbon monoxide easily penetrates into iron at the temperature around 500° C. (932° Fah.) and by decomposition deposits there carbon which is not really dissolved in the iron. Charpy appears, however, to have produced under these conditions superficial cementite which tends to show a certain solubility of carbon. However, industrial case carbonisation of iron does not begin until about 850° C. (1,562° Fah.). Steel subjected to case carbonisation often has an initial content of carbon of 0·3 per cent., not counting manganese, silicon, and other elements. The point of transformation in such cases easily reaches 780° C. (1,436 Fah.), and the carburisation once started, the piece of steel is rapidly covered by a thin layer of iron more or less saturated with carbon of which the normal temperature of transformation is only 700° C. (1,292° Fah.). Between this external layer and the core of the metal piece there are formed other layers of a transitional nature with regard to the point of transformation which gradually rises as the layer is deeper inwards. The diffusion of these layers from one to the other occurs the more rapidly the higher is the temperature used, but is very slow and more often ceases altogether at a certain point if the temperature is below the temperature of transformation in that region, hence the too sudden transition in the composition of the piece which may be harmful to the strength of the case carbonised layer. The pieces when case carbonised ought, therefore, to be heated at least up to 850° C. (1,562° Fah.). For the investigation of the results of the case carbonising operation two methods may be used—chemical analysis and microscopic investigation.

For the chemical analysis, very thin shavings from the surface of the metal might be taken by a milling machine and analysed, thus showing the distribution of the carbon throughout the depth of the piece. This process is very useful in scientific investigations, but cannot be conveniently applied in the shop where microscopic investigations are preferable. The microscope shows the thickness of the carburised layer with its variations in the content of carbon and the physical structure of the core, the transitionary layers and the periphery on which depends the cohesion of the various regions and the brittleness of the whole piece, but the microscope does not indicate the sulphur contents and the presence of occluded gases—factors of great importance for determining the quality of the final product. The author shows by figures how various iron-carbon compounds look under the microscope.

Thickness of carbonisation should be not more than one-third of the depth of the piece carbonised, since otherwise rupture through excessive brittleness of the periphery may be produced. If the piece is case hardened only on one side, however, it is said that the carbonisation may go as far as one-half of the depth. In cases where the carbonised piece is subject to shocks, it is necessary that the depth should be less than when it is subject only to static stresses.

As regards the selection of carbonising materials, the following general conditions may be stated: (*a*) The carburiser ought to have as high a velocity of carburisation as possible, since the longer the operation lasts the more expensive it is and the more chance there is for the metal to change its properties. It is also better to work at as low a temperature as possible. (*b*) The carburiser must not contain sulphurous matter, as the metal absorbs it and becomes hot short. At most there may be up to 2 per cent. of sulphur at a temperature between 900° and 950° C. (1,652° to 1,742° Fah.). At between 950° and 1,000° C. (1,742° and 1,832° Fah.) the sulphur volatilises. At the surface 0·88 per cent. of sulphur has been found. (*c*) The carburiser must be as good a conductor of heat as possible. This is important in order to minimise the errors due to the difference of temperature of the furnace and the pieces carbonised, each of the latter being heated in the powder in order to avoid the inconvenience of too long cooling. (*d*) It must have as low specific heat as possible. This property is necessary for the same reason as the preceding one. It is always well to heat up the box as quickly as possible, in order to avoid substantial errors with respect to the time of heating and its temperature, as well as to eliminate useless heating losses. (*e*) The carburiser must not alter the surface of the piece. Scratches, erosions, &c., require expensive machining and are harmful to pieces where precise dimensions have to be maintained. (*f*) Where brittleness must be avoided at all costs, it is necessary to adopt other conditions, often less compatible with the preceding ones, namely: (*a*) Progressive penetration of the carbon into the iron; a carburiser which acts too suddenly and roughly produces often hypereutectoid layers. When precision in the operation is required with the formation of the thin but hard layer the composition and action of the carburiser have to be very exact. (*b*) In addition to that, a good carburising powder has to satisfy the following conditions: (*a*) it must contain materials which can be easily powdered in order to give a uniform and close mixture; (*b*) it must not exhaust rapidly; good case carburisers can be used many times with great economy and regularity of results. (*c*) It must not be expensive; must be free of danger of explosions; and must not produce dust excessive in quantity or dangerous in action. (*d*) It must not decrease in volume while in the carburising boxes, since the heaping up of the carburiser would become unequal and some pieces undergoing case hardening might be left bare. Hence the necessity to avoid too fluid or volatile elements in the composition adopted.

The author discusses in detail the use of various carburisers—solid, liquid, and gaseous. Among solid carburisers

* Abstract of article by F. Robin in "Revue de Mecanique," and reproduced from the Journal of the American Society of Mechanical Engineers.

the best known are mixtures of carbon and salts, the carbon used being for the most part charcoal powder, the best being poplar charcoal which gives charcoal practically free from sulphurous matter. A mixture very widely used is that of charcoal and barium carbonate, the proportions generally adopted being 60 per cent. of carbon and 40 per cent. of barium carbonate. This mixture acts mainly through the evolution of carbon monoxide. Whether the presence of nitrogen is absolutely necessary for the carburisation or not has not been fully established. Barium carbonate is selected for its high temperature of dissociation. Calcium carbonate substituted instead of it gives an evolution of gas at considerably lower temperature, but the proportion of anhydride carbonate is much larger, which is not favourable to good carbonisation. The author shows by a diagram the depth of penetration with the mixture of charcoal and barium carbonate for various temperatures and lengths of carbonisation, prepared in accordance with the experiments of L. Guillet.

With a mixture of charcoal, barium carbonate, and ferro-cyanide, the admission of potassium ferro-cyanide appears to heighten the activity of the carburisation process and to increase the hypereutectoid layer at the temperatures of industrial case hardening. An interesting point to remember is that powder which has been used several times is still very good and often even better the second time than it was the first time, probably owing to the loss of moisture; no iron is found in the state of free ferro-cyanide when the heating took place at the high temperature. Mixtures of other salts have been tried with charcoal, giving practically analogous results to the use of the mixture of charcoal and barium carbonate, but the carbonising power of the material used would become exhausted much more rapidly. A mixture of charcoal and sodium chloride (10 per cent. of the latter) gives a good carboniser and possesses regenerative power, is very cheap and can be used for case hardening to a depth of 1 mm. (or ·04in.). It is, however, too long to heat. A French investigator, Grenet, mentions the following carburisers for use in shops. They are arranged in the order of speed of carburisation and price.

(*a*) A mixture of sawdust with forge coal containing 30 per cent. of volatile matter. (*b*) A mixture of pulverised charcoal, 1 kg., with 1½ kg. of sawdust and 0·1 kg. of sodium chloride. (*c*) A mixture of 0·5 kg. forge coal containing 30 per cent. of volatile matter, 0·5 kg. of carbonised leather, 0·1 kg. of sea salt, and 0·5 kg. of sawdust. (*d*) A mixture of 1 kg. of carbonised leather, 1 kg. of sawdust, and 0·2 kg. of ferro-cyanide. According to the patents of Lamargese, charcoal from certain definite woods, and especially from resinous woods, alone or with an addition of silicon, gives excessive hardness. Coke impregnated by residues from petroleum distillation is an active carburising material, but it is of irregular composition, which causes different results in different operations. A mixture of charcoal and concentrated solution of potassium-cyanide or charcoal and ferro-cyanide has been patented as a means of obtaining rapid case hardening admitting good practical control of results. It appears also that the view that the addition of cyanide of nickel or potassium bichromate to the carburising material produces penetration of nickel or chrome into iron, is incorrect.

In all the experiments which the author has made at the high temperature around 1,000° C. (1,832° Fah.), the most intense case carburisation appears to have been produced by a mixture of charcoal with 40 per cent. of barium carbonate. The most violent carbonisation with the largest hypereutectoid layer at all has been obtained by the use of carbon alone. There may be an infinite number of formulas by the use of which good results may be obtained as long as these formulas do not depart from the general rule: carbon, or products evolving carbon, added to little volatile salts, preferably carbonates or cyanides, which act as generators of gases with the carbon base, these salts being in a powder in a quantity equal to that of the carbon. The author only cautions against the use of toxic products or products giving off poisonous gases, as well as nitrogenous products which in mixture with the carbon may produce explosions. Saltpetre in particular must be used only with the greatest care, since otherwise a mixture approaching the composition of black powder may be produced. A mixture of 60 per cent. of saltpetre, 29 per cent. of prussiate, and 9 per cent. of colophonium gives also a rapidly acting explosive.

VALVES FOR WATER GAUGES.

THE accompanying sectional views show an arrangement of stop valve or cock for water gauges of the type in which there are two valves in series actuated by a common rotary spindle, the invention of Mr. R. Kilburn and Messrs. J. Hopkinson & Co., Ltd., Britannia Works, Birkby, Huddersfield. Figs. 1 and 2 are longitudinal sections of the valve, showing both valves closed. Fig. 3 is a section showing both valves open. A is the main valve mounted on a crank pin B on the inner end of the actuating spindle C, this valve being pressed against its seat D by a spring housed in a recess in the crank pin. The crank pin is circular in cross section, and the body portion of the valve, which is mounted on the crank pin, is cylindrical, so that the valve will be free to turn on the crank pin. The thoroughfare controlled by the valve A is indicated at F and forms a communication between the chamber G and the outlet H

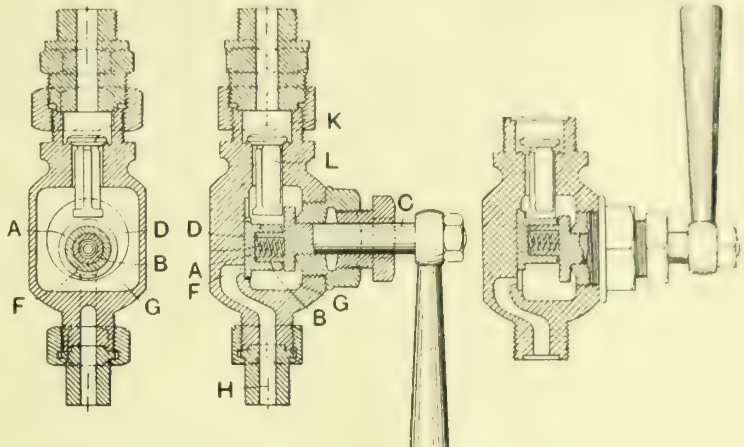


FIG. 1. FIG. 2. FIG. 3.

VALVES FOR WATER GAUGES.

This thoroughfare is closed when the crank pin B is in its lowest position, and is opened by turning the spindle C so as to raise the crank pin. The passage leading from the thoroughfare K to the chamber G is controlled by a lift valve L, the stem of which extends downwards and terminates at a suitable distance above the body portion of the valve A when in its lowest position. Upon turning the spindle C the thoroughfare F is first opened and then the continued rotation of the spindle C brings the valve A into contact with the stem of the valve L and lifts it. A backward rotation of the spindle C or a continuation of the rotation in the same direction allows the valve L to close and then closes the main valve A. The spindle C can be rotated in either direction to open and close the valves. Thus it will be seen that the main valve opens and closes its thoroughfare while remaining always in contact with its seat, thereby ensuring that the seat and valve face shall be kept clear of dirt.

Estimation of Zinc in Bronze.—In a paper read before the London Section of the Society of Chemical Industry Dr. T. K. Rose, chemist and assayer of the Mint, stated that the old method of estimating the zinc in coinage bronze, which was discontinued about 1870, has recently been revived. The advantage is the saving of time effected, the personal time of the assayer being occupied for only three to five minutes for each determination. The process consists in heating 1 gramme of the alloy for two hours in a reducing atmosphere at a temperature of 1,375° and weighing the residue. The sample is placed in a carbon crucible with a closely fitting lid, and eight to 16 of such crucibles are embedded in charcoal in a graphite pot and heated in an injector furnace. Coinage bronze consists of copper 95, tin 4, and zinc 1, and the loss of weight under the conditions named amounts to 1·2 to 1·3 per cent., about 0·03 per cent. of zinc being retained. Proof assays consisting of portions of a trial plate of known composition are included in each charge. The corrected results differ from each other by from 0 to 0·1 per cent., the average difference being 0·02 or 0·03 per cent. A few determinations have been made of the zinc in alloys containing various amounts up to 90 per cent., and found to agree with results obtained by the gravimetric and volumetric methods. As the amount of zinc is increased from 1 to 90 per cent. the loss of copper rises from 0·2 to 0·4 per cent.

OIL FUELS AND THEIR APPLICATION TO THE GENERATION OF POWER.*

BY PROF. THOMAS GRAY, D.SC., AND PROF. A. L. MELLANBY, D.SC.

THE rapid extension of the use of oil fuel during recent years was undoubtedly due initially to the accumulation of large stocks of petroleum, available at low prices, but the present widespread demand is to be attributed largely to a more general recognition of the greater convenience and efficiency of oil, compared with coal, and also to the development of the Diesel engine, which has placed at the disposal of the engineer a highly efficient method of utilising the energy latent in liquid fuels. The bulk of the petroleum employed at the present time for the generation of power is burned under steam boilers. Distilled oils from petroleum and tar and some crude oils have been extensively used in Diesel engines, but much work remains to be done before it can be definitely asserted that this type of engine is capable of dealing successfully with the many varieties of petroleum which occur naturally. Sufficient data have, however, been accumulated to permit of the following comparison of the relative values of oil and coal.

The Use of Oil for Steam Raising.—The oil is broken up into a very finely divided spray by forcing it through specially constructed orifices: (*a*) by means of steam under pressure, (*b*) with the help of compressed air, or (*c*) by supplying the oil itself under pressure. The flame produced by steam injection is more extended, and consequently cooler than that resulting from either of the other methods, on account of the formation of water gas by the reaction of the steam with the carbon present in the oil. The combustion space must, therefore, be ample, otherwise there is difficulty in effecting smokeless combustion. Provided this condition is satisfied, no difficulty is experienced, but the efficiency is reduced by the presence of the steam, which carries away into the flue a not inconsiderable proportion of the heat generated. Injection of the oil with air is a more rational method; as a portion of the air required for combustion is intimately mixed with the finely atomised oil, the area of flame is smaller, and the temperature is higher locally. To prevent the fuel from being driven too quickly through the combustion space, the injector should be constructed to give the oil a whirling motion, thus retarding its forward movement. In burners belonging to class (*c*) the oil is forced under pressure through spiral channels or against the edges of specially shaped cutters, and issues as a whirling mist. This type of burner has proved very successful in practice, and has been widely adopted.

The evaporative efficiency of oil, if thoroughly atomised in a well-designed burner, is considerably higher than that of coal. The results of numerous trials show that one pound of crude petroleum or residuum, with a net calorific value of from 18,000 to 18,250 B.Th.U's., will evaporate from 14½lbs. to 15lbs. of water from and at 212° Fah. This evaporation is approximately 50 per cent. greater than that resulting from an equal weight of good steam coal. These figures do not, however, represent the relative values of oil and coal as fuels in actual practice, since they leave out of account the decreased labour charges and other advantages of firing with oil. In large land installations, where the handling of the coal is performed by conveyers and mechanical stokers, the saving of labour resulting from the adoption of a liquid fuel does not constitute an important factor, but, on board ship, where hand stoking is practised, the change from coal to oil effects a large reduction of the number of men required As the oil is supplied to the burners automatically, and the cleaning of fires and the removal of ashes are unnecessary, one stoker is able to attend to a number of boilers. The bunkering of a ship with liquid fuel can also be carried out much more easily and quickly than with coal, with an entire absence of the dirt and disorganisation of work incidental to coaling.

The relatively small storage space required for oil is a further important consideration in the case of a ship. Assuming the evaporative power of two tons of oil to equal that of three tons of coal, and the volumes of one ton of oil and of coal when stored to be approximately 38 and 45 cubic feet respectively, the space occupied by a petroleum fuel is only from 55 to 60 per cent. of that necessary for the equivalent quantity of coal. Taking further into consideration the fact that oil may be stored in inaccessible places, such as between the double bottoms, from which it may be readily removed by pumping, it will be evident that the change from coal to oil will set free a considerable space for additional cargo. It is impossible to assess the value of these advantages without reference to a particular example, but the conclusion is obvious that the ratio of the value of oil to coal, weight for weight, for the generation of power on board ship, is very considerably greater than on land. Taking the various advantages of oil fuel into consideration, the value of petroleum for steam raising in a land installation is commonly assumed to be about twice that of coal.

The Use of Oil in Internal-combustion Engines.—Under favourable conditions of load, the thermal efficiency of the Diesel engine is stated to be 33 per cent., which corresponds, for an oil with a net calorific value of 18,000 B.Th.U's. per pound, to a consumption of 0·42lb. per brake horse-power per hour. The consumption of oil varies with the size of the engine, and is found in practice to range from a little above 0·4lb. of a petroleum oil in the case of a large engine, to about 0·5lb. per brake horse-power per hour with an engine of 25 h.p.

Comparing the lowest value with the performance of a high-class marine engine which will use from 1·5lbs. to 1·6lbs. of coal per hour per brake horse-power, we find that the weight of coal used in the combination of boiler and steam engine is from 3½ to four times the weight of petroleum oil necessary to perform the same work in the Diesel engine. If, on the other hand, the performance of the Diesel engine is compared with that of a steam engine supplied with superheated steam, the superiority of the former is less pronounced. Within recent years so-called locomobile engines have been developed, principally in Germany, which are guaranteed by the makers to operate with a consumption of ½ kg. (1·1lbs.) of coal per brake horse-power per hour. In these machines radiation losses are avoided by placing the engine directly above the boiler, and supplying the former with highly superheated steam. Taking this figure as a basis, the ratio of the weight of coal to that of oil necessary to develop 1 b.h.p. becomes from 1·1 to 0·4, or 2·75 to 1. There seems little room for doubting, however, that the adoption of high superheats in marine engines will become more universal as more experience is gained, and that both with turbines and reciprocating engines consumptions of the order of 1lb. of coal per hour per indicated horse-power will become common. On the other hand, a further advantage in favour of the oil engine is the practical absence of stand-by losses, which frequently account for a considerable proportion of the coal consumption when a steam engine is used intermittently.

Regarded solely from the standpoint of fuel efficiency the oil engine is admittedly far superior to the combination of boiler and steam engine, but the question of the relative costs of generating power by the two systems depends also on other factors, and can only be answered when the conditions under which the plant operates are specified. The initial cost of a Diesel installation is very considerably greater than that of a steam engine and boiler, and the higher interest and depreciation charges may more than counterbalance the saving in fuel costs. In localities where the cost of fuel is high, and the engine is running continuously, the fuel charge represents a large item in the total cost, and the advantage lies with the Diesel installation. If, on the other hand, fuel is cheap and the load factor low, the fuel costs are relatively small, and the conditions are unfavourable to the operation of the oil engine. The relative prices of oil and coal are obviously an important factor in the comparison of costs.

The high efficiency and other advantages of the Diesel engine are now generally recognised, but its adoption in practice is progressing comparatively slowly. This is accounted for by the natural reluctance of the power user to commit himself to a type of engine which can only deal with oil, until an adequate supply of suitable liquid fuel at a reasonable price is assured. There is also a disinclination on the part of engineers, who have experienced the convenience of working with steam turbines, to take what they consider to be a retrograde step in building an engine with heavy reciprocating masses. Conditions in Great Britain are, at the present time, unfavourable to the development of the Diesel engine, and the possibility of increased supplies of oil fuel, which is an

* Abstract of paper read before the Institution of Engineers and Shipbuilders in Scotland, January 20th, 1914

essential condition of further progress, has been widely discussed; we propose to deal at considerable length with this important aspect of the liquid fuel question in the present paper.

Classification of Oils.—The various industrial oils may be grouped into the following classes: Class I.—Petroleums, shale oils, lignite oils, and their products of distillation. Class II.—Coal tar and tar oils. Class III.—Vegetable and animal oils.

The oils which are grouped together in Class I. have similar chemical and physical properties, and are used for the same purposes. So far as Great Britain is concerned lignite oils and the oils of class III. may be eliminated from the above list. The production of crude lignite oil is confined to Germany, and the total output during the 20 years from 1890 to 1909 only averaged about 60,000 tons per annum. Vegetable and animal oils are produced in large quantities, but they command prices which remove them from the category of possible fuels. In the order of importance the petroleums stand alone; but interest in this country centres round the coal tars, shale oils, and the oils produced from these by distillation, and for this reason the space available for the present paper will be devoted largely to a discussion of these products.

Coal Tar.—This is a highly complex mixture, composed of hydrocarbons, phenols, compounds containing nitrogen and sulphur, free carbon, and variable quantities of ash and water; the nature of the two first-named classes of substances largely determines the commercial value of the material. Industrial tars are usually classed as: (1) Gas tars, including horizontal, inclined, and vertical retort tars, and chamber oven tars. (2) Coke-oven tar. (3) Blastfurnace tar. (4) Producer tar, all of which are derived from coal. (5) Water-gas and oil-gas tars.

The available information regarding the physical and chemical constants of the tars produced in this country is somewhat scanty. These properties, so far as they affect the suitability of tar for use as a fuel in internal-combustion engines, have, however, been more closely studied in Germany and Switzerland, and are dealt with comprehensively by Constam and Schläpfer in a paper which appeared in the Zeitschrift des Vereins deutscher Ingenieure* to which reference may here be made for a statement of previous work in the same field. From this source the following data are largely derived:—

Gas Tars.—These are produced as a by-product in the manufacture of illuminating gas by distilling coal in horizontal, inclined, or vertical retorts, and in so-called chamber ovens. The bulk of the gas produced in this country is still made in horizontal retorts, but these are being gradually replaced by retorts of the vertical type; the other forms referred to are relatively little used. Tar from horizontal retorts has a specific gravity of from 1·15 to 1·25; it may contain up to 35 per cent. of free carbon, and as much as 10 per cent. of water; normally the free carbon will average about 20 per cent., and the water from 3 to 5 per cent. The dry, ash-free tar contains carbon from 90 to 93 per cent., hydrogen from 4·5 to 5·5 per cent., sulphur from 0·3 to 1 (usually about 0·5) per cent., and leaves, on distillation, a residue of pitch amounting to from 55 to 65 per cent.; the higher calorific value ranges from 16,200 to 16,500 B.Th.U's. per pound. The lighter varieties contain the larger proportion of hydrogen, are low in carbon, and have the higher calorific value.

Tar from inclined retorts closely resembles that from horizontal retorts but is usually somewhat lighter. Constam and Schläpfer (*loc. cit.*) give the following limiting values for eight samples examined by them—specific gravity from 1·125 to 1·157, water from 1·1 to 7·3 per cent.; the dry, ash-free tar contained carbon from 89·3 to 90·4, hydrogen from 5·9 to 6·4, sulphur from 0·4 to 0·7, free carbon from 10 to 19·3 per cent., and had a higher calorific value from 9,096 to 9,207 calories per kilogramme (16,370 to 16,570 B.Th.U's. per pound). The residual pitch on distillation varied from 47·6 to 54·7 per cent.

Tar from vertical retorts more nearly approaches the low temperature product in character. On account of its greater fluidity, water separates more readily, and the settled tar usually contains less than 3 per cent. of water. The proportion of free carbon is generally less than 3, and frequently does not amount to 2 per cent. Constam and Schläpfer found the constants of 15 samples to vary between the following limits—specific gravity from 1·057 to 1·123, and, in the dry, ash-free tar, residue of pitch from 31·5 to 47 per cent., carbon from 87·6 to 89·9, hydrogen from 6 to 7·3, free carbon from 1·1 to 5·7 per cent., and gross calorific value from 9,167 to 9,479 calories (16,500 to 17,060 B.Th.U's. per pound).

Tar from chamber ovens resembles that from vertical retorts very closely. *Coke-oven tars* vary considerably, but, generally speaking, they resemble horizontal gas-oven tars, and are typically high temperature products. The free carbon is usually less than 10, though it may exceed 15 per cent. Constam and Schläpfer give for 12 samples the limits—specific gravity from 1·14 to 1·182; the dry, ash-free tar contained carbon from 89·6 to 92·2, hydrogen from 5·1 to 5·7, free carbon from 2·2 to 10·3, and had a gross calorific value of from 9,089 to 9,221 calories (16,360 to 16,600 B.Th.U's. per pound).

The majority of the tars referred to above contain a small proportion of ash, which, however, generally does not exceed 0·1 per cent., and frequently amounts only to a trace.

Blastfurnace tar production is practically confined to the West of Scotland, where splint coal is used for the reduction of iron ores in the blastfurnace. It is a low-temperature product. The specific gravity of the filtered and dehydrated tar is approximately 1·08. This variety of tar invariably contains a large proportion of ash. It gives from 33 to 35 per cent. by weight, or about 40 per cent. by volume, of an oily distillate, leaving a residue of about 65 per cent. by weight of pitch; the residual pitch may contain from 9 to 20 per cent. of ash.

Water-gas, oil-gas, and producer-gas tars represent a relatively small proportion of the total tar production of this country; a detailed description of their properties seems, therefore, unnecessary. For information regarding the two first-named varieties reference may be made to the paper by Constam and Schläpfer, already referred to.

The bulk of the tar produced in this country is subjected to distillation. In the raw state, or in the form of boiled tar, prepared by distilling off the light oil from the crude material, it is used for coating timber, metals, stone, and earthenware, in the manufacture of roofing felts, and for coating roads. The use of tar macadam has extended rapidly during the last five years, and the future consumption of tar in road-making is likely to have an important influence on the supply available for other purposes.

The value of tar as a fuel for steam raising is estimated by Wright and other authorities to be about 20 per cent. greater than that of coke. Crude tar, on account of the presence of varying proportions of free carbon and water, which interfere with the regular working of the injectors, has, however, never found favour as a fuel for steam raising, and its use for this purpose has rather been regarded as a convenient method of disposing of a material for which no other profitable outlet could be found.

The objections above referred to apply with even greater force to the employment of tar in Diesel engines, but the possibilities from the point of view of economy are much more attractive. From the results of a number of trials with a 100 h.p. Diesel engine, built by Körting, Allner draws the conclusions that coal tar from vertical ovens will be the future fuel for Diesel engines in Germany, but Kutzbach and Müller regard this view as unduly optimistic. Müller refers to the variable proportions of free water, carbon, and pitch in crude tars and states that they lack the constancy of composition which he regards as an essential quality for successful working.

Nägel reports on a 100 h.p. Diesel engine, built in the Nürnberg works for the experimental coke plant of Otto and Co. in Dahlhausen which had been running without interruption, Sundays excepted, since February 8th till the date of his paper (July). The tar employed was a black, viscous liquid at ordinary temperatures, having a lower calorific value of 8,300 calories per kilogramme, and up to 15 per cent. of free carbon; the price of the tar was from 20 to 21 marks per ton at the ovens.

Diesel classes "tars from horizontal and inclined retorts" as unsuitable, and "vertical-oven, water-gas, and oil-gas tars, probably also coke-oven tars," as suitable fuels if used with the aid of special apparatus. Constam and Schläpfer* give the physical and chemical constants of 74 samples of the

* Zeit. Ver. deutsch. Ingen., 1913, p. 1490.

* *Loc. cit.*, p. 1662.

different varieties of tar, some of which have been used in Diesel engines. Referring to the published information regarding industrial tars, they state that only those from vertical retorts and coke ovens, with one single exception, have proved suitable for the Diesel engine, the case referred to being a 750 h.p. engine which, however, was always worked at full load; the tar employed was derived from coal distilled in an inclined oven, and it is of interest to note, that the samples of this particular tar examined contained—water from 1·7 to 3·4, and free carbon from 11·6 to 12·6 per cent. The authors state that they are familiar with a number of cases of satisfactory experimental trials with vertical-oven tars over considerable periods, citing the constants of the tars used, but that they know of no case of continuous working under varying conditions in practice. They believe themselves, however, to be justified in concluding, from the results of their examination of vertical-retort and chamber-oven tars, that these are suitable fuels for Diesel engines, provided they contain only a small proportion of water and ash, and possess a high degree of fluidity.

Two cases of the employment of coke-oven tar are mentioned, one of these being the 100 h.p. engine in Dahlhausen already referred to. Constam and Schläpfer draw attention to the very variable composition of tars even from the same source, and emphasize the necessity of ascertaining before use the proportions of water, ash, coke, and free carbon, as the tars which are most fluid and contain the smallest proportions of these constituents give least trouble in actual use. They add that the tar oils are much more satisfactory fuels than the tars themselves, and that the effect of unburnt tar particles which form resinous deposits in the fuel valves, spraying arrangements, and pumps, should not be lost sight of. They suggest that suitable tars must possess the following qualities: Ash content—at most, a trace. Water—not more than 3 per cent. Free carbon—not more than 3 per cent. Lower calorific value—at least 8,600 calories per kilogramme.

From published evidence it appears that the use of tar in the Diesel engine has been largely experimental in character, and that the favourable opinions regarding the suitability of this fuel have not received the unqualified support of experts. Summarising the published evidence it appears that: (1) Gas tars from horizontal and inclined retorts are unsuitable. (2) Gas tars from vertical retorts and chamber ovens, generally speaking, give satisfactory results when used with an auxiliary fuel. (3) Some coke-oven tars are suitable. (4) Water-gas and oil-gas tars, if freed from the ash and water—often present in considerable quantity—give satisfactory results.

So far as Great Britain is concerned, the supply of tar which may be assumed, without further experiments, to be suitable is comparatively limited. The coal-gas and coke industries, in the order named, are the largest contributors to the tar output; the tar from the first source is still principally derived from horizontal retorts, though the replacement of these by vertical retorts is progressing steadily. A considerable proportion of the tar from coke ovens will probably prove to be too viscous to give satisfactory results in engines of the existing design.

(To be continued.)

APPROXIMATE MELTING POINTS OF COPPER ALLOYS.*

BY H. W. GILLETT AND A. B. NORTON.

In the course of investigations of brass melting furnaces it was necessary to determine the approximate melting points of a few of the common brasses and bronzes. The binary systems of copper-tin and copper-zinc alloys have been thoroughly worked out not only as to melting points, but as to the full phase rule relationships, showing the different phases present in the solid alloys at different temperatures, and also as to tensile strength. The United States Alloys Research Board, under Thurston, studied the mechanical properties of the ternary systems of copper-zinc-tin alloys in detail, but as pyrometers were not perfected at the time of that investigation the temperature measurements were confined to very crude ones on the pouring temperatures of the two binary, copper-tin and copper-zinc, systems, made by pouring the molten alloy into water, measuring the rise in temperature of the water and figuring the pouring temperature from the assumed specific heat of the alloy. The method, though the only one available at the time, was so crude and subject to so many errors that the figures are of little or no value. Experiments on the copper-zinc-tin system from the phase-rule point of view are in progress at Cornell University, but no melting-point determinations have yet been made. Thus, while the melting points of the two binary systems are well known, those of the commercial casting alloys containing copper, zinc, tin, and lead, or copper with two of the other components, have had little or no study.

Very few figures on the melting points of ternary and quarternary alloys can be found in the literature on alloys. Primrose mentions pouring gun metal consisting of 88 parts copper, 10 parts tin, and 2 parts zinc, at 950° C. (1,740° Fah.), this temperature being far too cold and giving a very poor casting of very low tensile strength, hence evidently not far above the melting point. This figure is probably not correct, as an alloy consisting of 90 parts copper to 10 of tin has a melting point of about 1,005° C. (1,840° Fah.), and 2 parts of zinc would probably not lower the melting point to such a degree. Primrose in a later paper shows a cooling curve for gun metal containing 88 per cent. of copper, 10 of tin, and 2 of zinc, with less than 0·2 per cent. of lead (exact analysis not given), which shows the melting point (liquidus) at 1,010° C., or slightly above that for a corresponding zinc-free bronze, although some lowering of the melting point by the zinc might be expected. Longmuir also poured some alloys at a temperature at which the metal would just flow, and so cold that in all cases the castings were poor and the tensile strength very low. The results obtained by Longmuir were as follows:—

Alloys.	Degrees. Cent.	Degrees. Fah.
Gun metal	965	1,770
Yellow brass	850	1,560
Red brass	1,058	1,935
Muntz metal	943	1,730

These figures also are probably not accurate. The remark made on the earlier figure by Primrose for gun metal applies here. The composition of the alloys was not given. If it be assumed that the names given have their normal significance the yellow brass would be about 65 parts copper and 35 parts zinc, an alloy which melts at about 915° C. (1,680° Fah.), and the Muntz metal would contain 60 parts copper and 40 parts zinc, an alloy which melts at about 890° C. (1,635° Fah.). Muntz metal has a lower melting point than yellow brass, not higher, as shown by these figures. Similarly, red brass of the common composition, which is about 85 parts copper, 5 tin, 5 zinc, and 5 lead, has a lower melting point than gun metal (taken as 88 parts copper, 10 of tin, and 2 of zinc).

Karr used a radiation pyrometer in determining the melting points and pouring temperatures of some copper alloys. For an alloy of 68·8 parts copper, 0·2 of lead, and 31 of zinc, he gives 1,640° Fah. (895° C.), which is considerably lower than the true melting point, evidently because of the well-known deviation from black-body conditions of molten copper or its alloys. He gives 1,650° Fah. (900° C.) as the melting point of one alloy containing 84 per cent. copper, 1,735° Fah. (945° C.) for that of another of the same copper content, and 1,850° Fah. (1,010° C.) for another said to correspond to gun metal, but containing no zinc.

Since the literature on the subject was found to be so meagre, it was decided to obtain figures on the melting points of a few typical commercial alloys with sufficient accuracy for the purpose in hand. The alloys were melted in a gas furnace. Instead of using the ordinary shape of crucible which exposes too large a surface to volatilisation and oxidation, crucibles were made from some bonded carborundum tubes which were in stock from a previous investigation.

The carborundum tubes were about 4·5 cm. inside diameter and had about 8 mm. walls. They were cut to about 15 cm. long and an artificial graphite plug was fitted at one end to form the bottom, luting it into place with alundum cement. Considering the cost of machining out a crucible from a graphite rod, as well as that of the graphite itself, these were much cheaper than artificial graphite crucibles,

* Paper read before the Chicago meeting of the American Institute of Metals. October, 1913

especially as they do not burn away anywhere near as fast as graphite. Their life was as long as that of the ordinary crucibles of fireclay and graphite mixtures. The temperatures were measured by a platinum, platinum-rhodium thermocouple used with a single pivot galvanometer.

The couple was calibrated against one which in turn had been checked against one calibrated by the bureau of standards, the secondary standard being read on a potentiometer, and the scale found to be correct within the limits of error of reading. The calibration was also checked up by reading the melting points of copper, of common salt, and of a bronze of 90 parts copper and 10 parts tin. The scale was correct within the error of reading at these points. The thermocouple wires were insulated by Marquardt tubing of 1 mm. bore and 2 mm. in outside diameter, and the hot junction was slipped into a Marquardt tube 30 cm. long and 9 mm. outside diameter and 5 mm. inside diameter closed at one end. The open end of this tube was fastened into an open-ended porcelain tube 35 cm. long, 10 mm. inside diameter, 14 mm. outside diameter by alundum cement. This arrangement served to protect the couple from zinc fumes or reducing gases. The end of the protecting tube was in turn protected from the molten metal by an artificial graphite boot, 9 cm. long and with 3 mm. walls.

There is a considerable time lag in the pyrometer reading when a cold protecting tube and boot is plunged into molten metal, but after the tube is once hot the lag is small. As the melting points were not determined by noting when the metal solidified, but by plotting temperatures against time, the proper temperatures for the heat evolution on freezing or heat absorption on melting should be shown even if there was some lag. About 600 grammes of metal were used in making the tests, the metals were weighed out in the proper portions to form the alloy desired, a slight excess of zinc, increasing with the increasing zinc content, being allowed to compensate for volatilisation. Electrolytic copper, Bertha zinc, and chemically pure lead and tin were used. The copper was melted first and covered with granular carbon and a little salt. When the copper was melted, the tin, the lead, and lastly the zinc were added, and the alloy well stirred with a graphite rod.

When the alloy was fully melted and mixed, the pyrometer was inserted and so clamped that the graphite boot did not touch the bottom or sides of the crucible. The gas flame was lowered and the temperature read every 15 seconds, stirring between each reading. When the alloy had frozen the gas was turned up and a heating curve taken. This was repeated several times. Zinc was continually volatilised from the melts containing zinc, but not in sufficient quantity to exert appreciable influence on the melting point, as duplicate runs agreed within 5° C. in all cases. After the runs were completed, the melt was poured in most cases into an ingot mould, sampled and analysed. As the analyses agreed well with the composition aimed at on the samples analysed, the melts not containing zinc were not analysed. Duplicate analyses of the same sample agreed within 0·1 per cent.

All the melts were made up from virgin metals except the sample of manganese bronze, which was in the form of test-bar ends from a previous investigation. It had tested 76,000 to 77,000 lbs. per square inch tensile strength and 24 to 35 per cent. elongation in the standard brick-form test bar. The bronze had approximately the following composition: Copper, 56 per cent.; zinc, 41 per cent.; iron, 1·5 per cent.; tin, 0·9 per cent.; aluminum, 0·45 per cent., and manganese, 0·15 per cent. As it was first cast into an ingot, then remelted and cast into test bars and these again remelted for melting point determination, the zinc content was probably nearer 40 than 41 per cent. and the copper nearer 57 than 56 per cent. when the melting points were taken. This sample was not analysed. The melting point given is the liquidus, or point given where freezing begins on cooling and ends on heating. This is more strongly marked than the solidus, or point where freezing ends on cooling or begins on heating.

The data obtained in the determination of the melting points of several alloys are given in Table I. As the results all checked within 5° C., an allowance of ± 10° C. or ± 20° Fah. is probably ample to cover all errors of reading and of calibration and use of the pyrometer. For comparison, the melting point (liquidus) figures for binary systems of copper tin, copper-zinc and copper-lead alloys for the range covering the common industrial alloys are given in Table II. The figures are only accurate to within about ± 10° C. or ± 20 Fah.

Although melting point determinations were made on only 11 alloys, those chosen represent a large proportion of the non-ferrous alloys in use in the ordinary foundry. Many of the other common alloys are near enough in composition to these or to the binary alloys, whose melting points are given, to allow obtaining the melting point by interpolation close enough for most technical purposes.

TABLE I.—*Results of Melting Point Determinations of 10 Alloys.*

Alloys.	Composition Aimed at. Per cent.				Composition by Analysis.				No. of Duplicate Determinations	Melting Point (Liquidus)	
	Copper.	Zinc.	Tin.	Lead.	Copper.	Zinc.	Tin.	Lead		C.	Fah.
Gun metal	88	2	10	—	—	—	—	—	4	995	1,825
Leaded gun metal	85½	2	9½	3	85·4	1·9	9·7	3·0	6	980	1,795
Red brass	85	5	5	5	—	—	*	*	8	970	1,780
Low grade red brass	82	10	3	5	81·5	10·4	3·1	5·0	4	980	1,795
Leaded bronze	80	—	—	10	—	—	—	—	3	945	1,735
Bronze with zinc	85	5	10	—	84·6	5·0	10·4	—	4	980	1,795
Half yellow, half red	75	20	2	3	75·0	20·0	2·0	2·0	3	920	1,690
Cast yellow brass	67	31	—	2	66·9	30·8		2·3	4	895	1,645
Naval brass	61½	37	1½	—	61·7	36·9	1·4	—	5	885	1,570
Manganese bronze	—	—	—	—	—	—	—	—	6	870	1,600

* (2 samples).

TABLE II.—*Melting Points of Three Binary Alloys.*

Copper-Tin Alloy.

Parts by Copper.	Weight Tin.	Melting Point. C.	Fah.
95	5	1,050	1,920
90	10	1,005	1,840
85	15	960	1,760
80	20	890	1,635

Copper-Zinc Alloy.

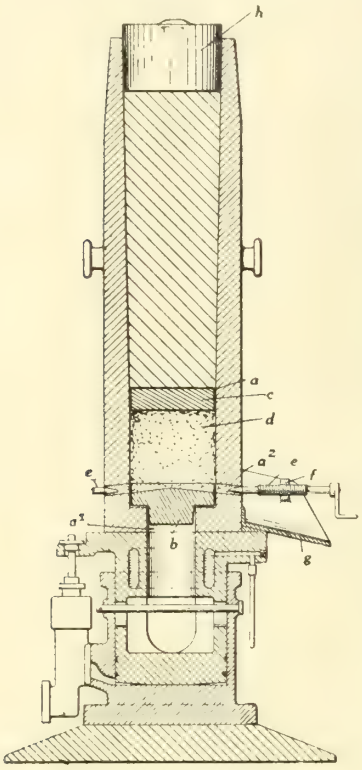
Copper.	Zinc.	C.	Fah.
95	5	1,070	1,960
90	10	1,055	1,930
85	15	1,025	1,880
80	20	1,000	1,830
75	25	980	1,795
70	30	940	1,725
65	35	915	1,660
60	40	890	1,635

Copper-Lead Alloy.

Copper.	Lead.	C.	Fah.
95	5	1,065	1,950
90	10	1,050	1,920
85	15	1,035	1,895

PRODUCING SOUND INGOTS BY JARRING.

A METHOD of producing sound ingots by jarring has, according to "The Iron Age," been patented by Mr. S. T. Wellman, Cleveland, Ohio. In carrying out the invention a tapered mould is used, having its upper end largest, with preferably vertical side walls from the point *a* downward, as shown in the illustration. There is a hole a^1 in the bottom of the mould, covered with a bottom plate *b*. The primary features are that the mould is partly filled by dry, free-flowing sand *d*, which rests on the plate *b*, and in turn supports the plate *c*; in the lower end of the mould there is an opening a^2, or several of them, through which this sand may slowly flow out. A conical pointed valve *e* screws through a lug *f* fixed to the side of a sand delivery spout *g*. The purpose of the plate *c* is to keep the metal from direct contact with the sand, and of the bottom plate *b* to afford a convenient means by which the solidified ingot may be forced out. While the metal is solidifying and being jarred the sand is allowed to flow out at such a rate as will allow the shrinking ingot shell to settle down and maintain contact with the side walls, thus being sufficiently compressed laterally to force the still fluid and pasty metal upward, filling what might otherwise become a permanent pipe and preventing the cracking of the mould. A heavy weight *h* at the top resting on the metal has been found of advantage.



APPARATUS FOR JARRING INGOT MOULDS.

THE PRODUCTION OF ALUMINIUM CASTINGS.*

BY J. W. COLLINS.

THE following remarks apply particularly to the production of such sections as automobile crank cases, oil pans, and transmission cases from an alloy consisting of 92 per cent. aluminium and 8 per cent. copper. The sand used for this work should be very fine and should contain only a small amount of clay. Sands high in clay will cause endless trouble from blows over projecting green sand cores, even when venting and skin-drying are resorted to. The sand also should be worked as dry as possible and still have it hang in the mould. In wetting-down the sand after shaking-out the moulds, great care must be exercised to prevent getting the sand too wet, as this fine sand does not absorb water readily. The general tendency is to get too much water and not enough shovel. Wet sand in the mould invariably means a bad casting.

Chills are used to bring about uniform cooling of a heavy section or boss, and a lighter section adjoining. They may be made of iron, brass, or aluminium, and should be made quite heavy to prevent breakage in removal from the castings and warping from the heat in continual use. Aluminium chills have the advantage over iron or brass when used in copes on account of their lightness, as they are less liable to fall out; however, regardless of the kind of chill used, they should have annealed nails cast into them, or projections cast on them, to assist in holding them in the sand. Stock chills, or chills of standard form, that may be used on a variety of jobs, are best made of iron, and for use in the drag of a mould where there is no danger of falling out, may be made heavy, from 1½in. to 2in. in thickness. One thick chill often will replace two or three thinner chills and will make a better-looking casting. Chills that are hot should not be used, as they dry out the sand around them, making a rough casting. Chills that have frost in them should not be used, as they will blow from the moisture that will condense on them in the mould.

In ramming the moulds for aluminium castings great care should be exercised to prevent ramming them too hard, thereby closing the pores of the sand. As aluminium is a light metal, being about 40 per cent. the weight of iron, it lacks the power to force the gas and steam back through the sand. Moulds that are rammed too hard will often produce a casting with a depression at some heavy section resembling a shrink, when in reality it is caused by the pressure of gas exerted on the metal while it is still molten. Hard ramming also is the cause of cracks in castings. This occurs, in some cases, where the design of the casting makes it necessary to crush a large body of green sand in contracting. However, light ramming can be carried to the point only where a casting will strain and become overweight.

In deciding on the best place to gate a casting, three factors are to be considered. First, the metal should be spread throughout the mould so that the casting may be poured fairly cold without danger of mis-running; second, the metal should enter the mould away from heavy bosses and ribs; and third, the gates should be located so that they may be removed easily by a band saw or chipping hammer. Some gates, however, may be broken off by a hand hammer where they are placed in a straight line; for example, along the flange of a lower half crank case or oil pan; but provision must first be made by casting a small groove in one side of the gate where it adjoins the casting. Horn gates are recommended, wherever they can be used, as they allow the metal to enter the mould with the least disturbance. The sprue and leader should be made heavy, so as not to freeze before the casting. Generous fillets also should be employed where the gate adjoins the casting. Risers should be used plentifully, as they give an added pressure and assist in making a sound casting. The removal of the risers also should be considered when placing them on the pattern, so that they do not break into the casting or draw the metal away from the casting in cooling. A good head pressure to carry on all sprues and risers is from 6in. to 12in., depending on the thickness of the uppermost part of the casting.

All moulds should be carefully inspected by the moulder as soon as the pattern is drawn, to see that the core prints are rammed sufficiently hard to support the cores and to see that the mould in general is rammed to the correct consistency to produce a good casting. The moulder also should be certain that all necessary chills have been used and are correctly placed. This is an important feature, when it is considered that the absence of one chill, or the misplacing of another, may mean the loss of a casting. This inspection applies more particularly to machine gangs, where the cope and drag are made by different men or teams of men, the moulder finishing the moulds and setting the cores.

In the general run of foundry work at least three core sand mixtures are necessary, the oil sand mixture for the small and intricate cores, and two mixtures containing resin, flour, or compound for the larger cores. One of the two latter mixtures is made about 50 per cent. stronger than the other. The weaker mixture is used for the general run of cores, and the other is employed when, on account of a core's design, extra strength is needed, and then only when rodding and wiring will not answer. The stronger mixture also is used when the drag half only of a complete core is made in dry sand, the cope half being made with green moulding sand. In the latter case, the entire weight is carried by the dry sand core. However, none of the mixtures should be stronger than is necessary to make a core that can be handled and placed safely in the mould. Soft cores are necessary for the following reasons: There is not enough heat in the molten aluminium to burn up the core, thereby softening it; aluminium is a weak metal at the point of solidification and has very little crushing strength just prior to solidifying. Cores that are too hard will cause the casting to crack. Hard cores also will cause trouble in removing them from the castings, as the cores are seldom burned to a greater depth than ½in. to ¾in.

Chills are used in the cores on heavy bosses and at the intersection of ribs, the same as in the moulds. If there is

* Abstract of paper read before the Detroit Foundrymen's Association, January 8th, 1914.

any danger of the chills falling out of the core while it is green or after it is dry and placed in the mould, they should have nails cast in them, or projections cast on, to anchor them firmly in the core. Applying paste to the chills will also assist in holding them in place. In designing chills and in deciding where to place them to remedy a crack or draw in a casting, one thing must be remembered, and that is the chill must come out of the casting easily.

A great many rods and wires are necessary to strengthen and support cores for aluminium castings. This is due to the weak sand mixtures used. The rods should be as short as possible, and, if a long core has metal around each end, the rods should be used in short, overlapping length. Straight rods are preferred to crooked or bent rods, unless they are bent to conform to the core box as the latter resists the crushing of the core by the casting when contracting. The ends of rods should never be placed close to the sides or ends of a core box, except into core prints, as they will sometimes cause the casting to crack, or even force themselves through the casting. It is necessary to handle nearly all of the larger cores with hooks, as they are broken easily if placed in the mould with the hands or straps used under them. These hooks should be firmly anchored in the core and placed so that the core will balance when picked up.

To get a smooth surface on the cores, they must be treated with a wash of some kind. This is best applied with a spray, while the cores are green, and afterwards brushed over with a camel hair brush and clear water. The brush and water also can be used to clean off the chills, which lose their effect if covered with a coating of core wash. The core wash also serves to give the core a hard crust on the outside, which helps to prevent breakage of corners when handling.

The baking of the cores is an important item and should be done with a slow, steady fire and under pyrometer control. If care is not exercised, the corners and edges will be burned before the centre of the core is dry. Resin sand cores should never be handled while hot, as they are easily broken. After the cores have been removed from the ovens, they should be thoroughly cleaned and inspected to see that all excess core wash has been removed from the ribs and bosses. The location of all small cores that have been pasted into the main core also should be checked with a suitable gauge.

In melting, aluminium should never be heated to a temperature higher than is necessary to pour the castings, allowing for a drop in temperature in dipping and transferring to the pots in which it is carried to moulding floor. A temperature of 1,500° Fah. will usually take care of this. As soon as the metal is hot enough, it should be thoroughly stirred and skimmed, then dipped out and carried to the moulds. The metal in the furnaces should be under pyrometer control and also should be kept covered during melting. In dipping the metal from the furnaces, if iron melting pots are used, care should be exercised to prevent scraping the sides of the pots. Hard spots in castings are sometimes attributed to the metal that clings to the sides of the melting pots. To avoid this, the sides of the pots should be scraped clean two or three times a day. To prevent over-heating the metal and to get it to the floor hot enough to pour, arrangements should be made to preheat the dipping and pouring ladles. The best method of pouring the moulds is by a gang specially trained for this work, and a great deal of the moulding gang's time is saved by this system. Each job has a best pouring temperature, which, in nearly all cases, is as low as the casting will run. This, of course, has to be found by experiment. When this has been ascertained, use a pyrometer on every floor and on every pot and the perplexities of mis-run castings will be removed.

Institute of Marine Engineers: Lloyd's Register Scholarships.—These scholarships, two in number, were founded through the instrumentality of the late Mr. Jas. Dixon (chairman Lloyd's Registry of Shipping), past president of the Institute of Marine Engineers. They are each tenable for two years at £50 per year. Application should be made by intending candidates not later than May 1st. Full particulars of the rules and regulations with list of subjects for examination may be obtained from the Secretary, Institute of Marine Engineers, 58, Romford Road, Stratford, London, E.

SOME RAILWAY CONDITIONS GOVERNING ELECTRIFICATION.*

BY ROGER T. SMITH.

In a country like ours, possessed of a system of steam railways which have cost more to build than railways elsewhere, it seems reasonable that if any change from steam to electricity is proposed by electrical engineers they should first endeavour to provide something which will at least do what steam will do, next try to give electrically what steam cannot give, and finally do this in such a way as will result in improved financial prosperity to the railway. It is convenient to divide railway services into three groups which correspond to entirely different conditions as far as traction is concerned: (1) Urban and suburban passenger services. (2) Fast passenger services. (3) Fast or slow goods and mineral service.

It is not pretended that this exhausts the types of services for which it is profitable to consider electric as compared with steam haulage. For instance, the electrification of terminals is not included, nor incline working, nor the marshalling of passenger and goods trains, nor the working of goods and mineral shunting yards. The above division is sufficient, however, for the purpose of such generalisation as is alone attempted in this paper.

Urban and Suburban Passenger Service. If a railway possessing a suburban system equipped with permanent way, platform accommodation, and locomotives designed for a certain time table, finds this equipment outgrown by the traffic, it is obvious that it must increase the number of coaches run in a given time. To do this several courses are open. (1) It may double or treble the number of tracks and increase both the number and length of its platforms, thus increasing the number of passengers carried without necessarily increasing the journey schedule time. (2) The railway may retain its permanent way and stations and with them the maximum length of its trains, but increase their schedule speed by using the biggest type of steam locomotive permitted by the load gauge for running comparatively light suburban trains. (3) The railway may electrify. With electrification a maximum of 48 trains an hour can, if required, be run each way during the rush hours while employing existing stations and tracks. With tracks and stations (hence also the train length) remaining as before, the number of passengers carried per hour has in many cases been doubled by increasing the schedule speed 50 per cent., while improved signalling has at the same time made it possible to increase by 50 per cent. the maximum number of trains per hour. The characteristics of urban and suburban services for which electric traction is suitable are a dense or fairly dense service of not less than, say, five trains per hour each way, up to 40 and more per hour each way, with station stops varying from less than half a mile apart up to 1½ miles apart. With services less dense than the minimum, and with stops further apart on the average than the maximum here given, the advantages of electric traction, if they exist, are special and not characteristic.

The essential element which gives to electric traction its advantage over steam under these conditions is the motor-coach train. The train is made up either entirely of motor coaches or of motor coaches and trailers. The number of motor coaches must be such that the weight on the driving wheels available for adhesion is not less than 25 per cent. of the total train weight. It is more often 33 per cent., and may be 100 per cent. The making up and driving of such trains has been rendered possible by multiple-unit control. With the motor-coach train it is quite easy to have such an adhesive weight as will permit of a tractive effort, over and above that required to haul the train against resistances, sufficient to accelerate it during the notching period at rates up to 1½ miles per hour per second (2·2ft. per second per second), while the rate of deceleration is usually increased up to two miles per hour per second. Such a rate of acceleration is not often justified, and a more characteristic example may be taken from one of the London suburban services where trains weighing 175 tons are accelerated, during the notching period, at 1·7ft. per second per second to

* Abstract of paper read before the Institution of Electrical Engineers.

give with 20-second stops a schedule speed of 17 miles per hour, the station stops averaging half a mile apart. The adhesive weight is 46 per cent. of the train weight, and the energy input while accelerating is 1,300 h.p. Within the load gauge of this railway no steam locomotive could be built of such a power. If it could be built it would have (in order to give the necessary adhesion and power) four times the weight of the electrical equipment, which is distributed over eight axles.

Although belonging more to the economic than the engineering side now under consideration, the cost in energy of such a reasonable acceleration and schedule speed, which is about that of most of the London underground railways, is shown in Fig. 1, representing actual tests of 20 such trains, the rate of acceleration being constant at 1·7ft. per second per second, while the distance between stops varied, giving an average schedule speed over the whole distance of 17 miles per hour. The energy in watt-hours per ton-mile at the train includes the moving and controlling of the train only; brake pumping, lighting, heating, and idle mileage being excluded. Other advantages of the multiple-unit-controlled motor-coach train, as has often been stated, are first the doubling of terminal accommodation by halving the number

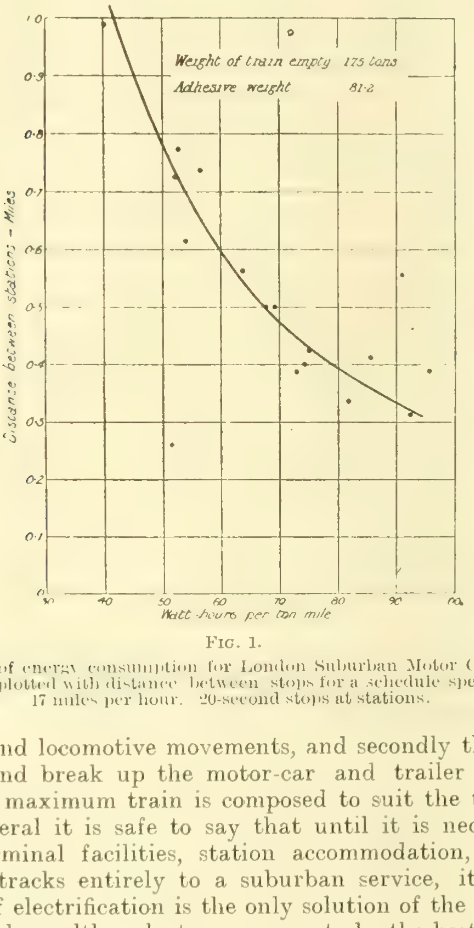


FIG. 1.

Curve of energy consumption for London Suburban Motor Coach Train plotted with distance between stops for a schedule speed of 17 miles per hour. 20-second stops at stations.

of signal and locomotive movements, and secondly the ability to make and break up the motor-car and trailer units of which the maximum train is composed to suit the traffic.

In general it is safe to say that until it is necessary to devote terminal facilities, station accommodation, and at least two tracks entirely to a suburban service, it is very doubtful if electrification is the only solution of the congested traffic problem, although it may prove to be the best solution. Most of the suburban services into and out of London already electrified or in process of being electrified are run on tracks distinct from the main line, and such a service becomes a thing apart. It can be electrified on any system which best suits its conditions, and the method may be quite different from any other method which may subsequently be desired for main-line electrification.

Passing from the engineering to the economic side, the question of the electrification of a suburban system has become for a railway company purely one of finance. Essentially it resolves itself into a question as to whether the fares charged for the service, even with the additional traffic obtained, can give a reasonable return, or any return at all, upon the new and old capital, after the cost of working has been provided for. It must be remembered that the tramway uses the streets and pays only for its construction, for part of the paving, and for a part or the whole of necessary street widenings. The railway has paid for the land—often acquired compulsorily at an exorbitant price—and has to put on the land costly permanent way and structures. Usually a railway company is the largest ratepayer in any parish through which it passes, and is often the largest ratepayer in any town. It may therefore be called upon to pay rates to a municipal body on which it is not represented, in order to keep up part of the roads used by a competing tramway. If the municipal tramway is run at a loss the railway helps to pay the losses of a competitor whose presence reduces the railway fares.

The tramway in turn is now menaced by the competition of the motor omnibus, which pays nothing beyond the petrol tax for its right to use the roads in order to compete with both railway and tramway. Even when it cannot make the development of its suburban traffic pay directly it may still pay the railway as a whole considered only as a feeder to the main line, or urban and suburban traffic as a whole may pay if the latter goes far enough out into the country. It is not that suburban electric traction costs an unreasonable amount, but that circumstances make the revenue from such services unremunerative. Suburban fares have been falling steadily, and at the present moment it is safe to say that everybody in London and its suburbs is being carried at too low a fare to give proper remuneration to any form of traction which, in addition to rates and taxes and government duty on some fares, pays for its road and the right to use it.

Like most other industrial working costs, that of running a suburban service depends on certain standing charges which, taken as a whole, do not vary, or hardly vary, with the service given (upkeep of permanent way equipment, management, rent, rates and taxes, and station traffic expenses) and a charge varying with the service catered for (rolling-stock, repairs and wages, running wages and electricity). In a particular case the ratio of standing to variable charges for running a small suburban service for a year was as follows: Standing charges unaffected by the number of trains 60 per cent., variable charges 40 per cent., and of this 40 per cent. electricity formed three-fourths. If the cost of electricity can be reduced by 50 per cent. the total working costs may be reduced by one quarter, which shows the importance of cheap electricity. This is a particular case where the cost of electricity was high, and as a rule its percentage effect is not so great.

Fig. 1 shows how, for a given average schedule speed, the distance between stops affects the amount of electricity used, and supposing it were possible to have a differential tariff for railway passengers based on the actual cost of the service, the short-distance passenger ought to pay much more per mile than the long-distance passenger, since he costs more to carry; but on nearly all suburban services competition has cut down the fares of the short-distance passenger to a non-profitable point. What is wanted to make urban traffic on electrical lines pay is either an increase in the fares, which is achieved abroad by zone fares, or the ability to purchase electrical energy delivered to the conductors at say ¼d. per kilowatt-hour Competition may prevent the former. Is there any chance of obtaining cheaper electricity? The generation of electrical energy and its supply is a business in itself. In many cases it has not in the past been possible for railways electrifying suburban services to buy electricity from outside, but wherever they have been able to do so the saving of the initial cost on which capital charges have to be met, and the saving to the railway of the management of a business organisation that is very different from its other organisations is a great gain. In general the addition of a load, which in the case of a heavy suburban service may continue during 18 or 20 hours out of the 24 with an annual maximum demand load factor of from 45 to 55 per cent., should enable a supply authority with a light and power load to offer a railway company such a price as would leave no question as to its acceptance.

To sum up the situation with regard to suburban electrification as it appears to the author, the electrical engineer is in a position to inform his railway very exactly what the initial and working cost will be. The management have to decide what the financial result will be with the existing and expected traffic, which has to pay working and capital charges on the new capital before earning a dividend

on the old. Competitive fares are so low that the process is generally discouraging except where a new traffic can be created in districts from 10 to 30 miles from the terminus. The cost of electric working is important, but as Mr. Insull has recently pointed out the cost of money may be still more important, and the raising of fresh capital for anything that is not certain to swell the dividend is a very serious matter indeed at the present time when the credit of British railways stands so low.

Fast Passenger Service.—When the condition of frequent stops and short distances between them is left and the question of main-line passenger services as run by steam locomotives is considered from the point of view of electric traction, the problem alters completely. The chief difficulty in the way of electrification for fast passenger services is the existence of the steam locomotive. Fig. 2 gives curves kindly supplied to me by Mr. G. J. Churchward, of draw-bar pull plotted against the speed for two types of steam locomotives, one for passenger service (the 4—6—0 type) and one for goods service (the 2—8—0 type). The curves represent the average results for saturated steam of many experiments with each type of locomotive hauling actual trains, the draw-bar pull being measured by the dynamometer car. The two types of locomotives may be taken as representative, one for hauling fast passenger trains and the other for hauling fast goods trains with nearly the maximum loading on the coupled axles permissible for British way and structures. They also represent approximately the maximum powers which can be developed by steam locomotives built within British load gauges, which are not the same for all our railways. Constant-output draw-bar horse-power curves are added for guidance. Curves of an American and of a French steam locomotive of the 4—6—2 or Pacific type are added for comparison.

As compared with the electric locomotive the steam locomotive is handicapped by the distribution of weight due to the length of the boiler. In the former, from the shape and size of the motors, it is possible to get a greater ratio of adhesive to total weight than in the latter, especially if every axle is driven. In general for fast passenger service the acceleration of the steam locomotive is limited not only by the boiler capacity but by the maximum adhesive weight on the coupled driving wheels. The 4—6—0 type locomotive can haul a train of 450 tons on the level at the highest speeds called for in this country and unassisted a train of 300 tons up a gradient of 1 in 50. The maximum length of the train is in general limited by the minimum length of the station platforms, and without radical changes in station structures no heavier trains can be run except for occasional "rush" traffic. To haul such a train, a constant-output locomotive is satisfactory, and the control of the output and speed by the regulator and the cut-off is so complete that the steam locomotive can run at any speed below its upper limit for the load hauled.

The problem of getting the adhesion necessary to prevent the slipping of the wheels when starting is, in general, possible with appreciably lower axle loads than for the steam locomotive, while for the same tractive effort the advantage in total weight is always in favour of the electric locomotive. Since the series motor can be overloaded momentarily 75 per cent. above its hourly rated capacity, while for adhesion purposes if necessary every axle can be made a driving axle, even greater starting torques than those shown in Fig. 2 are possible, but on British railways they would be not only useless but actually harmful, exceeding the draw gear strength. Unlike the case of the multiple-unit train, the adhesive weight may be only 12 or 14 per cent. of the total train weight, and the strength of the draw-gear limits the draw-bar pull after starting to 12 tons. But with an increase in speed the torque of the series motor falls off so rapidly that above 60 miles per hour (where difficulties begin with steam locomotive design) no electric locomotive yet built for hauling only such maximum loads as obtain on our railways could give anything like 1,100 h.p. at 70 miles per hour, as given by the 4—6—0 steam locomotive shown in Fig. 2. This diagram shows tractive effort curves of a few fairly modern American electric locomotives, the loads representing not draw-bar pull, but tractive effort at the rims of the driving wheels, so that the hauling of the locomotive itself is included. They are added to show how very quickly the tractive effort at the rims of the wheels falls off at high speeds. Such locomotives are only of academic interest to us, as their starting effort is quite beyond the strength of draw gear on British railway passenger stock.

Turning from the engineering to the economic side, and assuming a suitable electric locomotive has been built, a very rough estimate may be made of the cost of working, more with the purpose of showing the direction in which economies are desirable than of giving any figure that can be used for estimating purposes. The annual cost of a steam passenger locomotive, averaged over all the different types in use on a railway carrying passengers, goods, and minerals over not less than 2,000 miles of route, and hauling its own locomotive coal, may be taken to be £825 for such items as do not vary with the mileage run, or only vary to an extent which will not affect this first approximation. These include capital charges (which are taken at 6 per cent. for interest and obsolescence), administration and management, wages of drivers and firemen,

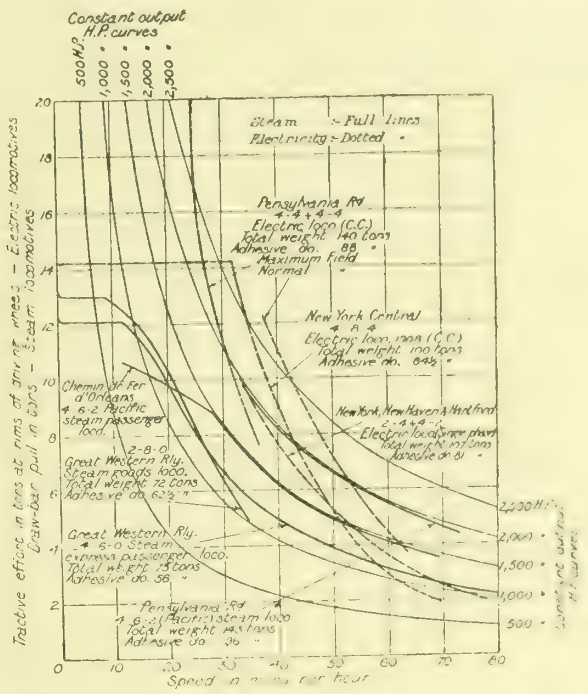


FIG. 2.
Curves of maximum continuous draw-bar pull (steam locomotives) and maximum tractive effort at driving wheel rims (electric locomotives) plotted against speed.

oil and small stores, maintenance, repairs and renewals. To this is to be added the cost of coal and water, varying more or less directly with the mileage, which for passenger service may be conveniently taken as the train mileage. The annual cost of coal at about 9s. per ton per 10,000 B.Th.U. averaged over the whole working together with the cost of water may be taken to be £350, giving a total for the year of £1,175 inclusive of capital charges. This is a mean for all locomotive types working an average passenger mileage of 10,000,000 train miles per 1,000 miles of route. During the year a passenger engine may be expected to run between 25,000 and 30,000, or say 27,000 passenger train-miles, so that the mean cost for locomotive expenses (including locomotive capital charges) per train-mile will be 10½d.

Of the above sum of 10½d. per train-mile, 3d. per train-mile will represent the cost of coal and water. After the coal strike in 1912 the cost per ton went up 2s., but neglecting its present high, but fluctuating value, and taking the cost of the best English coal used at 12s. 6d. per ton, to which 3d. per train-mile corresponds, cheap coal in this country is one of the factors making against railway electrification. The cost of coal burnt in a large modern generating station producing electricity for hauling trains by an electric locomotive is less than half the cost of coal for doing the same work in a steam locomotive. Weight for weight the electric locomotive costs about twice as much as the steam locomotive, but for the same adhesive weight the electric locomotive weighs some 30 to 40 per cent. less than the steam locomotive. Electric

repairs and renewals cost less, and the net result is that the annual cost of the electric locomotive will be in the neighbourhood of £1,250 per annum, assuming the same rate for capital charges. But while the passenger steam locomotive only runs on the average 27,000 train-miles in the year, spending 75 per cent. of the time out of active service, the electric locomotive, which need only be in the shops for one month out of the 12, will not spend more than 50 per cent. of its time out of active service. The electric locomotive can run at least 40,000 passenger train-miles per annum. There is not much experience to go on, and that experience has been wholly obtained in other countries. The suburban working in London, where electric locomotives are used, is so restricted that no figures are obtainable which can be compared with steam working. Multiple-unit motor-cars run 45,000 to 50,000 miles per annum. If these figures are accepted, the cost per train-mile with the electric locomotive (including locomotive capital charges) will be 7½d., always assuming that electrical energy can be bought at ½d. per kilowatt-hour.

It must again be emphasized that these figures can only be considered as a first approximation to the truth, and they will differ for different railways. But assuming that for a railway running 10,000,000 passenger train-miles per 1,000 miles of route, the conditions enabled electric locomotives to run 40,000 miles annually, so that a saving of 3d. per train-mile was secured by electrification, there would be a possible annual saving due to electrical working of £125,000. If capital charges (interest and amortisation) were 6 per cent., this would represent the charges on a capital of £2,100,000 per 1,000 miles of route, or £2,100 per mile of route. This sum would certainly not cover the corresponding electrical equipment of the line on an overhead system, inclusive of contact wire and structures, distributing cables, bonding, and sub-stations. The only items for which a reduction in costs may be expected are the cost of electricity and the capital cost of electric locomotives. No great reduction in the cost of the former can be expected so long as railways generate their own electrical energy, as there must be a diversity of load and generation on a scale far beyond railway requirements, to secure an appreciable reduction in price. If electrical energy could be bought at ¼d. per kilowatt-hour, and the electric locomotive could be made for £50 per ton, the cost per train-mile in the above estimate would be reduced to about 6d. The problems in front of the electrical engineer who would compete with the passenger steam locomotive are, therefore, first to design an electric locomotive that will do what the steam locomotive does at high speeds; secondly, to reduce the cost of the electric locomotive (which will come about when there is sufficient demand for it); and thirdly, to be in a position to buy electrical energy at something approaching the ¼d. per kilowatt-hour which forms Dr. Ferranti's ideal.

Fast or Slow Goods and Mineral Service.—For goods and mineral service the outlook is different, and in consequence the form of analysis from averages which was admissible to prove a negative is not admissible to prove a positive. For goods and mineral services each individual case must be worked out on its merits. It may, however, be said that if the same analysis be followed out in the case of the average cost of an electric locomotive for goods working as has been done for passenger working, the same comparative ratio of cost between coal and electricity per train-mile would hold with electricity at ⅓d. per kilowatt-hour —the price at which it can in some cases be obtained to-day— in place of the ½d. per kilowatt-hour assumed for passenger service. Considering English conditions the chief difference between goods service and passenger service is the reduction in the annual train mileage run by the steam locomotive. Whereas for steam passenger service it was taken to average 27,000, for goods and mineral service it drops to 10,000 train-miles per locomotive. In addition to this the coal per train-mile is nearly doubled. On the average some two-thirds of the available steam locomotives may be expected to be in steam on any one day, and of those engines in steam the engine mileage will probably exceed the passenger train mileage by little more than 5 per cent. On the other hand, goods engine mileage may exceed goods train mileage by more than 30 per cent., owing to the many services that the locomotive has to perform other than moving trains from station to station. Each goods engine in steam may not work more than 40 to 50 train-miles per day averaged throughout the year, which gives some idea of the length of time the locomotive is standing in steam and using coal but earning nothing, while nearly one-third of the engines are away under repairs.

It is in this direction that the electric locomotive appears to have its best chance. In America it has been found to be possible at least to double the daily mileage run by a steam locomotive, owing to the ability of the electric locomotive to haul heavy loads at an increased speed while it wastes no energy when standing idle. Instead of more than 30 per cent. of the steam locomotive year being occupied in repairs, not more than 10 per cent. of the electric locomotive year need be spent in the repair shops. Fig. 2 shows the available tractive efforts of one or two electric locomotives in America at low speeds, but American conditions are not our conditions, and a locomotive giving a starting pull much greater than the 2—8—0 steam locomotive is of no use for goods service in this country. In America the strength of the draw-gear is such that draw-bar pulls of more than 30 tons are permissible, and trains of 3,500 and 4,000 tons weight can be hauled if fitted with continuous brakes. In British goods and mineral service the limiting factor is the strength of the draw-gear, which is tested to 50 tons and with a factor of safety of 4 is supposed to be worked at a maximum load of 12 tons.

We are not really limited in our train weights by the maximum size of steam locomotive which can be built within the restricted British load gauges (restricted, that is to say, as compared with America and many European countries), but by the strength of draw-gear and the lay-out of sidings. While the wagons owned by railways can have their draw-gear maintained against inevitable degradation by fatigue and wear, the privately-owned wagon is not in the same position. Unless the whole method of working goods traffic in this country is to be altered, a locomotive is not required to give a draw-bar pull of more than 12 to 14 tons after starting, and even then the failures of draw-gear will always be considerable with the shocks when starting a loose-coupled train, and with the stresses due to unequal braking. The draw-bar pulls of the American electric locomotive shown in Fig. 2 if used on a British goods or mineral train would merely break the couplings.

The methods of electrification available for the consideration of the engineer are varied, but for goods working involving the equipment of sidings some form of overhead equipment seems imperative. Continuous-current, single-phase with commutator motors, single-phase with split-phase motors, and single-phase with mercury arc rectifiers and continuous-current motors, and 3-phase with induction or cascade motors, are all possibilities, and each has to be considered on its merits. It is not within the scope of this paper to discuss systems, but it may be pointed out that owing to the special conditions of goods and mineral traffic in this country —a few of which have been referred to in this paper—the electrification of goods and mineral lines is likely to begin only in favourable districts, especially with steep grades where the overload capacity of the electric motor and its accelerating ability will enable traffic which is now very slow to be speeded up. This will increase the earning capacity of the existing permanent way without costly re-grading. The electric shunting engine is a very good example of what has to be done in the matter of suitable design. A shunting engine may be called upon for hours to push heavy trains of wagons at two or three miles per hour and then to clear away a train of empties at 25 miles per hour. It is frequently called upon to push or pull a heavy loaded train over a weighbridge with a pause long enough for the weight to be recorded while each wagon is on the bridge. This the steam locomotive can do, but the continuous-current series-motor locomotive with continuously rated resistances seems hardly an engineering competitor of the steam locomotive for such work as this. There is far more hope for the single-phase locomotive.

To sum up the position as it appears to the author—the inherent advantages of the electric locomotive for goods and mineral haulage are, first, its ability to haul up to the maximum strength of the draw-gear at more than double the speed possible with the most powerful steam locomotive which can be built within British load gauges; secondly, the ability if necessary to have all axles driven, so that the whole weight of the locomotive is available for adhesion while the weight per axle is sensibly reduced; thirdly, the advantage that any

driver can work any locomotive, which is not the practice in this country with steam locomotives; fourthly, the ability to run annually at least twice as many train-miles as the steam locomotive, partly due to increased speed, and partly due to less time spent in the repair shops, and for cleaning; fifthly, the saving of all coal wasted by the steam locomotive when getting up steam, standing in steam, and left in the firebox at the journey's end, with the result that with electrical energy at ½d. per kilowatt-hour the bill for current per mile is about the same as the bill for coal and water per mile; sixthly, the possibility when the strength of the draw-gear permits of loads being hauled quite beyond the capacity of any steam locomotive that can be built within our load gauges. The electric locomotive takes its power from a generating station and not from a moving boiler; it can therefore be designed to give its maximum draw-bar pull at any desired speed. It is for the electrical engineer to make the most of such advantages.

DESIGN AND CONSTRUCTION OF HYDRAULIC TURBINES.*

H. BIRCHARD TAYLOR, M.AM.SOC.M.E.

DURING the past ten years hydraulic turbine design has passed through a stage of wonderful development and, in respect to many features, remarkable progress has been made toward bringing the turbine to a high state of perfection. As a result of theoretical investigation, substantiated by experimental research of the highest order, efficiencies have been increased on the average about 10 per cent. Corrosion of runner vanes, at one time a serious factor as affecting the maintenance of turbines and their efficiencies, has been eliminated subsequent to conclusive demonstration that it is primarily the result of defective design. The development of high specific speed runners, thereby permitting the use of higher rotational speeds, has resulted in the rapid passing away during the past few years of the multi-runner types of turbines in favour of the vertical-shaft, single-runner type. At one time it was generally thought that the character of speed regulation of a turbine was dependent entirely upon the governor. To-day, however, it is known that the make or type of governor has little or nothing to do with speed regulation, except in so far as it must have sufficient power and proper mechanical adjustments to move the turbine gates in a certain time and without hunting.

Efficiency.—Ten years ago it was considered a notable achievement to obtain in a turbine in place an efficiency as high as 82 per cent. The average of the best results secured was in the neighbourhood of 80 per cent. The maximum guarantees of the builders were from 78 per cent. to 80 per cent., and were considered highly satisfactory. During the past two years, efficiencies between 89 per cent. and 92 per cent. have been quite common, while a maximum value of 93·7 per cent. has been secured. To-day the builder must guarantee an efficiency of at least 87 per cent. in order to secure business. This remarkable increase in efficiency is by no means entirely due to superior runner design. As a matter of fact, the improvements in the design of wheel-casings, wicket gates, draught chests, and draught tubes have increased the efficiency of the turbine as much as the more efficient runners.

In comparing designs prepared ten years ago with recent designs, the most striking feature is the absence in the latter of sudden turns and abrupt changes of section in all water passages from the turbine casing to the tail-race; and, although in the older designs these passages were thought to be consistent with good results, they now appear to be exceedingly crude. The elimination of losses due to eddies and whirls, abrupt changes of section and sudden curvature in the various parts which constitute the turbine has improved the efficiency of the turbine as a whole. By means of the Pitot tube, it has been possible accurately to determine the conditions of flow in the various parts of the turbine casing, through the guide vanes, in the space between the guide vanes and the runner, and also in various sections of the draught tube. Thus it has been possible to compare actual conditions of flow in these various parts with the calculations.

The head corresponding to the velocity of discharge from the runner into the draught chest or tube may represent a considerable proportion of the total head acting on the turbine. This is especially true in the case of runners of high specific speed, where this velocity head may be as great as from 25 per cent. to 30 per cent. of the total head acting on the turbine. It is therefore essential to design the draught tube most carefully, in order to convert this velocity into effective head. Improvement in the design of draught tubes has been very marked, and has resulted in a considerable increase in the efficiency of turbines. It has only been within recent years that the hydraulic conditions within the draught tube have been fully appreciated. It was at one time thought that the draught tube was simply a device by means of which it was possible to locate the turbine above tail-water level without losing the effective head represented by the difference in elevation between the turbine and the tail-race. To-day, however, the draught tube is looked upon as an extremely important part of the turbine; in fact, it may be said that without efficient draught tubes runners of high specific speeds would be impracticable.

There have been built in times past quite a number of draught tubes with constant diameter from the runner to the tail-race. Consequently, the velocity which existed in the section immediately at the discharge from the runner existed also at the end of the draught tube, and the energy represented by this velocity was entirely lost to the turbine, in addition to the frictional loss resulting from the condition of high velocity throughout the entire length of the draught tube. The efficiency of turbines with draught tubes so designed is necessarily extremely low. By properly designing the draught tube from the section immediately at the discharge from the runner to the tail-race so that the velocity is gradually reduced from a maximum at the runner to a minimum at the tail-race, the vacuum in the draught tube may be increased and, consequently, the effective head on the turbine.

Until the last two years a large majority of the turbines installed in connection with low and medium heads were of the old-fashioned multi-runner type, consisting of two, four, six, and sometimes more runners on a shaft, these runners being grouped in pairs, each pair discharging into a common draught chest and tube. The energy represented by the velocity at the discharge from the runners was practically lost to these turbines, owing to the losses due to impact and eddies and whirls existing in the draught chests and tubes as a result of the runners discharging against each other. Consequently, there was practically no reconversion of the velocity head from the runners into useful head.

Ten years ago the draught chest and draught tube designs of turbines of these types were exceedingly crude. Improvements have been made, of course, from time to time, until the multi-runner unit, as now built, is quite an efficient machine. The principal improvements have been in allowing a greater distance between the runners which discharge into a common draught chest, and in designing the draught chest so that the water from each runner is carried into the draught tube to a point where the two streams are moving in parallel directions, before allowing them to converge; but even with the best design of turbines of the multi-runner type there is always present an appreciable loss due to the comparatively sudden turns which the discharge water from the runners must necessarily follow.

In many of the power developments carried out a number of years ago, and in some few instances in more modern plants, even such efficiency as could be obtained from the turbines cannot be realised in the operation of the plant as a whole. Poor designs of the waterways leading to the turbine casing and receiving the discharge from the draught tube cause considerable losses outside of the turbine passages. In some instances much attention has been given to slight variations in turbine efficiency, while losses of head amounting sometimes to one or two feet, occurring through submerged arches, bridge piers, or racks, have been overlooked.

Corrosion of Runner Vanes.—Corrosion, or pitting, of runner vanes, guide vanes, and draught tubes is now pretty well

* Abstract of paper read before the Canadian Society of Civil Engineers, January 15th, 1914.

understood and, by correct designing, can be eliminated. Corrosion, or pitting, must be distinguished from erosion, which is mechanical wear due to the presence of foreign substances in the water. Erosion is entirely a mechanical action, while corrosion, or pitting, is the result of chemical action. It has been demonstrated that corrosion is primarily a question of design. It has been clearly shown in practice that where sharp curves are resorted to, where contraction is not sufficient, or where there are pockets formed in the surface of the vanes, pitting or corrosion inevitably develops. It has also been demonstrated that where air in large quantities is entrained in the water carried to the turbine, corrosion seems to take place very rapidly if the design is not correct. While it is true that corrosion takes place more quickly under high heads than under low heads, runners operating under heads as low as 25ft. to 30ft. have been found in some cases to corrode very rapidly. It is, therefore, essential that the runner be carefully designed, regardless of the head under which it is to operate, but extreme precaution must be taken in cases where the head is excessively high. A corroded vane surface has an appearance resembling a sponge, the surface being extremely irregular and the pitted spots often opening holes entirely through the vane. Chemical analysis of the corroded surfaces has brought out the fact that the metal has been oxidised. In runners made of bronze or an alloy, modifications in the composition have been detected in the corroded portions.

The theory of corrosion as now generally accepted is that the water in passing over any pocket or depressed surface, or in failing to adhere to the surface of the vane, leaves spaces which are filled with eddies possessing high velocities and very low static pressure, in which oxygen is liberated from the water. This oxygen is believed to be in the nascent state, and rapidly attacks the surface of the metal, forming an oxide coating, the greater part of which is rapidly washed away by the water. When once the depth of this pocket is increased by corrosion, it is natural that, due to the greater area exposed, the pitting action should continue at an accelerated rate until the vane is entirely eaten through. It is quite likely that electrolysis is present as a result of the oxidation of the metal, for it has been noticed in connection with runners of the built-up type—viz., runners in which plate-steel vanes have been used with iron or bronze bands and hubs—that corrosion seems to develop more rapidly than in the case of runners made of uniform metal. Foreign engineers have called attention to the fact that in some instances they have observed that the metal eaten out by corrosion at one section of the runner has apparently been redeposited at another section, a condition evidently resulting from electrolysis. If electrolysis does exist, it is a secondary action, and may be eliminated by first preventing corrosion.

The fact that a runner develops high efficiency under test is not, necessarily, a guarantee that corrosion will not take place. Small defects in the curved surfaces of the runner vanes will be very quickly brought out by the fact that they corrode; while, on the other hand, these defects in the flow through the runner may be too small to be detected in an efficiency test. In general, however, it may be said that high efficiency and freedom from corrosion are complementary qualities. While corrosion is primarily caused by defective design, some metals are more susceptible to its action than others. For example, bronze resists corrosion better than does either cast steel or cast iron; but if the runner is so designed as to permit corrosion to take place, it matters little what metal is used. Runners regulated by means of cylinder gates are particularly subject to corrosion, owing to the eddies produced behind the cylinder gates at fractional gate openings. Corrosion will often develop in a runner if the turbine is operated continuously at low gate openings. The falling-off of the efficiency of a turbine at low gates is an indication that the hydraulic conditions within the runner are greatly disturbed, and this disturbance tends to promote corrosion. High specific speed runners, if applied to high heads, are also subject to corrosion, owing to the high velocities to be dealt with and the difficulty in making the water follow the radical curves characteristic of the vanes of these runners.

Corrosion has often been greatly accelerated because of poor draught tube conditions. It is evident that should the total draught head, or the sum of the static draught head and the velocity head at the runner discharge, exceed the height of the water barometer, the continuity of flow of the water on leaving the runner is destroyed. When the absolute static pressure in the draught tube falls to a value equal to the vapour tension corresponding to the temperature of the water, the water will vaporise and the draught tube will not be filled with a solid column of water from the tail-race to the runner. Therefore, the placing of a turbine simply within 34ft. from the elevation of tail-water is no indication that the elevation has been properly chosen; for aside from the limitations outlined above, it is also necessary to allow at least 3ft. or 4ft. margin between the total draught head and a perfect vacuum to prevent the breaking of the column of water in the draught tube due to inertia effects resulting from sudden changes of load on the turbine. It must also be borne in mind, and this is a point which has been frequently overlooked, that in figuring the margin between the maximum vacuum and the total draught head, the maximum vacuum should be considered for the particular elevation above sea level at which the turbine is to be installed.

In respect to erosion, although the best metals are used in resisting its action, and high factors of safety are adopted in all parts of the machinery which may be subjected to it, erosion must necessarily be expected wherever the quality of the water is such as to produce it.

The High Capacity Runner, and the Vertical Single Runner Turbine.—Until two years ago, a very large majority of turbines applied to low heads were either of the vertical shaft multi-runner type, or of the horizontal-shaft multi-runner type. The reason for using more than one runner on the shaft which, from a mechanical standpoint, is not desirable, was that this arrangement permitted high rotational speeds, and, therefore, economic sizes of generators. During the past two years, however, the general adoption of the single-runner vertical-shaft turbine for low and medium heads has been witnessed. This change in the type of unit has been made possible by recent progress in the design and development of high-capacity runners. Thus, for a given head and speed it is now possible to secure from a runner a greater output than was possible two or three years ago; or, conversely, for a given head and capacity it is possible to operate the more recently designed runners at a much higher rotational speed than was the case with runners designed a few years ago. This increase in the capacity of runners has been secured without a sacrifice of maximum efficiency and with only a small sacrifice in the efficiency at fractional loads.

In referring to the capacity of a runner, there is a certain relation between head, speed, and power output which is best expressed by a theoretical characteristic known as "specific speed" (N_s). This characteristic was first introduced by German engineers. It gives us a means of comparing the relation between the conditions of speed, head, and power of a runner in one installation with the same conditions relative to a runner in a totally different installation. This comparison is made after the conditions governing the design of both runners have been reduced to a common base, viz., specific speed.

The specific speed of a runner may be defined as the speed at which any runner will operate when it is reduced to such a size that it will develop one horse-power when operating under a head of unity. The numerical value, expressed in the metric system, of the specific speed of any runner may be found by first calculating the speed and power output of the runner under consideration for one metre head, and then mathematically reducing the runner in size until it will deliver one horse-power. The speed of this reduced runner, when operating at its point of maximum efficiency is its rated specific speed, and this speed is expressed in the formula

$$N_s = R\,P\,M \times \frac{\sqrt{HP}}{h^{5/4}}$$

the quantities being expressed in the metric system. For

converting this to the foot pounds system of units, the formula is

$$N_s = 4{\cdot}45 \times R\,P\,M \frac{\sqrt{HP}}{H^{5/4}}$$

in which the horse-power and head are expressed in the foot-pounds system, while the N_s remains in the metric system. The specific speed as calculated from this latter formula is the one generally used. In figuring the specific speed of any turbine having more than one runner, the horse-power used in the formula, of course, is the output of each runner.

An examination of the formula will show that for a given revolution per minute and head, the horse-power output is proportional to the square of the specific speed; also that for a given head and horse-power, the revolution per minute of a turbine is proportional to the specific speed. Five years ago a specific speed of 275 was considered to be quite high, while to-day a specific speed of 400 is secured, together with as high a maximum efficiency as was previously secured with a specific speed of 275. Thus, to-day it is possible with very high efficiency to secure for a given condition of head and power, and with the same maximum efficiency, a speed in the neighbourhood of 50 per cent. greater than was possible five years ago; or, for a given head and speed, an increase of approximately 100 per cent. in the horse-power can be obtained.

With the highest specific speed which could be secured five years ago, the resulting revolutions per minute for a vertical shaft single-runner turbine for low heads was, in a great majority of cases, such as to make the cost of both the turbine and generator prohibitive. During the last two years, however, with runners of increased specific speed, a much higher rotational speed can be secured for the same head and power, so that the turbine and generator designs have become thoroughly practical and economical. Although it is true that the rotational speed secured in such a turbine is low when compared with the speed secured with turbines of the same specific speed and having two or more runners, there are many mechanical advantages involved in the use of the single-runner vertical turbine for low heads which more than over-balance the increased cost of the generator.

Among the principal advantages of the single-runner unit are the following:—

(1) Only one gate mechanism is required, and this is located above the head cover of the turbine and is accessible at all times for inspection while the unit is in operation. The only parts of the turbine that are submerged are the runner and the guide vanes. Repairs can be made to the gate-operating mechanism without dismantling the turbine.

(2) Owing to the fact that only one gate-operating mechanism is used, involving a small number of parts, the chance for breakage is reduced to a minimum, and lost motion and deflection in the governor engine connections are avoided.

(3) It is possible to secure in a single-runner unit an ideal draught tube of long tapering section, without an obstruction or sudden turn. Therefore, with this type of wheel it is possible to use runners of the very highest specific speed, as the draught tube can be designed to convert the velocity at the discharge from the runner buckets into effective head with small degree of loss.

(4) With a single runner vertical unit, it is possible to mould in the concrete a spiral turbine casing similar in design to the cast-iron spiral casings used in connection with high head turbines. It would be impracticable to prepare spiral casings for vertical or horizontal turbines having two or more runners, for obvious reasons. In a single runner turbine operating in a spiral casing the water is directed to the runner at uniform velocity around its entire circumference, producing more uniform operation and higher efficiency thereby. In the case of the multi-runner vertical or horizontal wheels, however, it is necessary to set these wheels in open flumes or cylindrical casings, in which case the water is not guided uniformly to the runner. Consequently, the approaching water is in a more or less turbulent state from eddies and whirls. In order to eliminate excessive loss in efficiency due to these eddies and whirls, it is essential to keep the velocities extremely low in the flume by increasing the dimensions of the flume, and therefore the distance between wheel centres.

(5) It is very often possible with turbines of the single runner vertical shaft type to locate the runner and gate mechanism above high tailwater level, so that after the closing down of the head gates and drainage of the wheelpit, an attendant may examine all parts of the turbine without first having to pump out the wheel chamber.

The advantages enumerated in favour of the single runner vertical wheel have made that type of turbine most desirable for low head installations and also for many high head developments, and undoubtedly this type of unit will be very generally adopted in the future.

(To be continued.)

INDUSTRIAL AND TRADE NOTES.

Coal and Iron Output of Germany.—The output of coal, including lignite, in Germany rose from 259·4 million metric tons in 1912 to 278·6 millions in 1913. The total output of raw iron in Germany and Luxembourg last year was 19·29 million metric tons, as compared with 17·85 millions in 1912.

Utilisation of Waste Heat at Ironworks.— The Whitehaven Hematite Iron and Steel Company have, we understand, decided to lay down at their ironworks at Cleator Moor a plant for converting waste heat into electric power, which will be sold to the mines in the Cumberland iron ore field. The plant will be similar in type to that which has proved so satisfactory and profitable at several iron and steel works on the East Coast, but the project is a pioneer one for Cumberland.

Light Railway.—The Board of Trade have recently confirmed the under-mentioned Order made by the Light Railway Commissioners: County of Hertford Light Railways (Watford and Bushey Abandonment) Order, 1914, authorising the abandonment of part of the light railways authorised by the County of Hertford Light Railways (No. 1) Order, 1904, and of the light railways authorised by the County of Hertford Light Railways (Watford and Bushey Extensions, &c.) Order, 1908, and for other purposes.

A Large Motor Ship.—There was launched from Messrs. Harland and Wolff's yard at Glasgow on the 11th inst. the twin screw motor-vessel, "Mississippi," for the Atlantic Transport Line. The vessel, which is the first ship built by the firm to be propelled by internal combustion engines, is 383ft. 9in. long over all, 50ft. 4in. in extreme breadth, and of about 5,000 tons gross. She will be fitted with two four stroke cycle, single acting Diesel engines, each coupled direct to its line of shafting, and two four-stroke cycle, single-acting, auxiliary Diesel engines, each coupled direct to its dynamo and air compressor. Each of the main engines has six cylinders, 26⅜in. (670 mm.) in diameter and of 39⅜in. (1,000 mm.) stroke. With 105 revs. per minute the normal horse-power will be 1,600 i.h.p. for each engine.

Employment in German Industries in 1913.—According to the German Imperial Statistical Department, the past year has proved a distinctly unfavourable one for German industries. The very satisfactory condition of employment which prevailed at the beginning of 1913 gradually gave way to a decline, which became particularly noticeable during the latter part of the year. Returns covering about two million workpeople show a rise in the proportion unemployed from April onwards, when 2·3 per cent. were out of work, to a maximum of 4·8 per cent. in December a higher figure than any recorded since the returns were first collected (in 1903); secondly, that the figure in each month of 1913 is distinctly higher than that for the corresponding month of 1912. The average works out to 2·9 per cent. in 1913, as against 2 per cent. in 1912.

Employment in the Engineering Trades.— According to the "Board of Trade Labour Gazette," employment in January was good on the whole, and showed no marked change compared with the previous month. The engineering and shipbuilding trades continued busy, and employment at coal mines was still very good. Wages in the iron and steel trades continued to fall; in other trades there was still some upward movement. The changes taking effect in January affected 46,400 workpeople, of whom 19,700 received increases and 26,700 sustained reductions, the net effect of all the changes being an increase of just over £200 per week. The number of new disputes in January was 54, and the total number of workpeople involved in all disputes in progress was 61,783, as compared with 59,026 in December, 1913. The estimated total aggregate duration of all disputes during the month was 694,800 working days, as compared with 907,700 in December, 1913.

Consolidated Diesel Engine Manufacturers, Ltd.—As a result of the unfavourable report published by this company some little time ago, a committee of shareholders was appointed to investigate the position of affairs, and the results of its deliberations have now been presented in no less than three reports. The one signed by the majority of the committee concludes that the arrangement existing with Messrs. Usines Carels Frères should be terminated, and states that the committee have concluded a pro-

visional agreement for the purchase by Messrs. Carels of the 10,001 shares held by the Diesel Company in their firm for £150,000, to be satisfied by the payment of £50,000 in cash and 100,000 shares in the Diesel Company now held by them. The committee do not propose to take action against the directors. They recommend reconstruction with a view to carrying on the Ipswich works alone. The new company would have a capital of £500,000 in 10s. shares, 750,000 being issued, and each shareholder would be entitled to apply for three new shares with 7s. paid for every two now held. The second report urges a voluntary winding up, and the third strongly opposes the disseverance of the Ghent and Ipswich works, and recommends the adjournment of the coming meeting with a view to a meeting between the Board and three or four of the largest independent shareholders, when a guaranteed scheme might be formulated which should safeguard the company's assets.

Status of the Consulting Engineer.—At the inaugural dinner of the Association of Consulting Engineers recently held, Mr. J. H. Balfour-Browne, K.C., said the association represented an attempt to keep the profession of engineering on the heights. He could conceive no worse fate for engineers than that they should become an instrument of manufacturers or the slave of municipal corporations. In order to maintain a profession at its highest level it should have an external conscience in addition to the individual consciences of its members, and the association, with its rules for moral guidance, was a conscience of that kind. With regard to trade and commerce the members of the association must stand in splendid isolation. New trades ought not to be handicapped by the competition of public departments operating with funds provided by the very people with whom they were competing. Further, State and municipal engineers should not be allowed to compete with what he would call ordinary consulting engineers. They should devote all their time and attention to the work of the municipality, with adequate pay, and if they did that adequately they ought to have no time for engaging in private practice. There was also the danger that the municipal engineer acting in a consulting capacity was liable to have a narrow outlook. The variety of work engaged in by the consulting engineer was his strength, and was calculated to give a judicious breadth to his decisions which was invaluable to his client.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1912.

Locomobile steam generators and superheaters. McCourt, and Bonecourt Surface Combustion, Ltd. 24113.
Pumps actuated by the motive fluid in internal combustion engines. Walker. 24173.

1913.

Driving belts. Walton. 1476.
Transmission gearing. Naumann. 1806.
Percussive rock drills. Kirsch. 2081.
Apparatus for cooling and cleaning gases. Wollaston. 2114.
Two-cycle rotary explosion engine. Patrick & Peterson. 2151.
Furnaces for steam boilers. Brewtnall. 2254.
Metallic packing. McDonnell. 2259.
Apparatus and system for treating ores. Durand & Stapley. 2300.
Grinding and polishing machines. Lardinois. 2324.
Alloys containing cobalt. Haynes. 2487.
Valves and valve-actuating mechanism. Shilston. 2498.
Braking of machinery. Brown, Boveri, & Co., and Thallmayer. 2586.
Process for the manufacture of iron. Rubel. 3445.
Speedometers. Brown. 5456.
Carburetters for internal-combustion engines. McGregor. 5496.
Flues of steam generators. Lord. 7387.
Arrangements for clearing soot from steam boilers. Jobling. 7841.
Internal-combustion turbine. Scott. 8007.
Production of aluminium from its compounds. Giulini. 8166.
Hoisting machinery. Clarke, Chapman, & Co., and Woodeson. 8256.
Sand moulding machines. Wade. 9098.
Mill bar heating furnaces. Diether. 9358.
Traction engines. Heer. 10037.
Carburetters for internal combustion engines. Eiker. 11192.
Steam generators. Meikle. 11564.
Parallel slide valves or cocks. Lees & Lees. 11815.
Reaction propelling mechanism operated by gas explosion for ships. Baltzinger. 12159.
Formation of gear wheel teeth. Parsons & Cook. 13981.
Device for extracting tubes from condensers and boilers. Jones. 14134.
Fluid pressure pump governors. Crittenden. 14399.
Lifting and chain hauling jacks. Barker. 14491.
Starters for explosion engines. Lecocq & Van der Aa. 14799.
Automatically starting explosion engines. Dupont. 15269.
Apparatus for measuring the pressure of gases. Piller. 16130.
Railway rail joints. Broomhall. 16837.
Welding iron and steel. Eisengraber. 17046.
Continuous ingot-heating furnaces. Siemens. 17955.
Smoke-consuming device for fireboxes. Boyce. 18269.
Internal combustion engines. Kalianjee & Paranjape. 18433.
Railway rail joints. McCoy & Bowersox. 18723.
Steam heaters for railway vehicles. Wild. 19980.
Internal combustion motors for self-propelling torpedoes. Royer. 21018.
Mills for grinding, crushing, and pulverising ores. King, and Head, Wrightson, & Co. 22476.
Machines for fluting twist drills. Strong. 25562.

ELECTRICAL, 1913.

Manufacture of tungsten. British Thomson-Houston Company. 1915.
Dynamos. Lee & Oldfield. 1990.
Controlling electrically-operated mechanism. Brunn. 2295.
Electric safety lamps for mines. Attwater. 2372.
Storage battery charging. Simon, Roberts, & Chadwick. 2469.
Time mechanism for operating electric switches. Horstmann, Horstmann, Horstmann, Horstmann, & Edgar. 2588.
Electrical switches. William McGeoch & Co., and Reynolds. 2757.
Transmitting apparatus for use in wireless telegraphy and telephony. Marconi. 2918 and 2919.
Electric switches. British Thomson-Houston Company. 3462.
Electric motor-control systems. British Thomson-Houston Company. 3684.
Electricity prepayment meters. British Insulated and Helsby Cables, Ltd., and Wilson. 4472.
Generators of electric current for ignition purposes. Vendervell and Midgley. 5013.
Regulation of dynamos. British Thomson-Houston Company. 6285.
Battery compounds. Mackenzie. 7298.
Incandescent electric lamps. Lowden. 7722.
Track contact devices for electric tramway vehicles. Helfenstein. 8267.
Electrical connectors of the plug and socket type. Lundberg, Lundberg, Lundberg, & Pegg. 11960.
Electrical high-tension indicator. Stephenson. 18975.
Telephone transmission circuits. Western Electric Company. 20179.
Electrical regulating switches. Hulbert. 23110.
Transmitter of electric-writing telegraphs. Widegren & Widegren. 29241.

METAL QUOTATIONS.

TUESDAY, FEBRUARY 17TH.

Aluminium ingot	86/- per cwt.
,, wire, according to sizes, &c. ......from	112/- ,,
,, sheets ,, ,, ... ,,	112/- ,,
Antimony	£27/10/- to £29/10/- per ton.
Brass, rolled	7½d. per lb.
,, tubes (brazed)	9⅝d. ,,
,, ,, (solid drawn)	8¼d. ,,
,, ,, wire	7⅝d. ,,
Copper, Standard	£65/2/6 per ton.
Iron, Cleveland	50/9 ,,
,, Scotch	56/9 ,,
Lead, English	£19/17/6 ,,
,, Foreign (soft)	£19/10/- ,,
Mica (in original cases), small	6d. to 3/- per lb.
,, ,, ,, medium	3/6 to 6/- ,,
,, ,, ,, large	7/6 to 11/- ,,
Quicksilver	£7/10/- per bottle
Silver	26½d. per oz.
Spelter	£21/6/3 per ton.
Tin, block	£180/15/- ,,
Tin plates	13/4½ ,,
Zinc sheets (Silesian)	£25/-/- ,,
,, (Stettin ; Vieille Montagne)	£25/2/6 ,,

The Mechanical Engineer.
An Illustrated Weekly Journal
Vol. 33, No. 840.

Edited by
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Telegrams: "Scientific," Manchester.
Telephone No. 6655 City.

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Advertisements, displayed, for insertion in current issue should reach our Manchester office not later than first post Tuesday morning, and small prepaid advertisements not later than first post Wednesday morning.

The Value of Boiler Inspection.

A STRIKING illustration of the value of inspection for preventing boiler disasters has been furnished by the report of the Chief Government Inspector of the United States Locomotive Boiler Inspection Department. The reputation of the United States for boiler fatalities of all kinds has for a long time been notoriously bad, and, as regards the general run of boilers on land, if we except locomotives, shows little sign of improvement. It is certainly no exaggeration to say that for one serious boiler explosion in this country there are 20 in the States, but these do not come before the public eye so prominently as locomotive failures, which probably accounts for the special cognisance which government authorities have at last taken with respect to failures on railways. How greatly it was needed is shown by the fact that, notwithstanding the little imperfections inseparable from the introduction of a new system, and that attention has been mainly concentrated on the more serious defects, the figures show a reduction of over 60 per cent. in the number killed, and 10 per cent. in the number injured by failures of locomotive boilers and their appurtenances during the year ended June 30th, 1913, as compared with the preceding year, though the accident rate still remains high and during the last year resulted in 36 people being killed and 911 injured. That the rate is still on the down grade is clear from a comparative summary of the accidents recorded during the first and last quarters of 1913, the figures for which give 214 for the former, as against 106 for the latter. Seasonal fluctuations may of course affect these figures slightly, but it cannot account altogether for the satisfactory diminution shown, and it would appear that 1914 will provide the Chief Inspector with quite as good a text for his sermon on the importance of boiler inspection as the figures in his report recently published. So evident and immediate have been the good effects brought about by skilled and periodic supervision, not only as regards

boilers, but also as regards engines and other parts, owing to the incidental discovery of defects in the course of boiler examinations which are a fruitful source of accidents and derailments, such as cracked and broken wheels, loose tyres, badly-worn flanges, &c., that the report concludes with the recommendation that Congress should legislate with a view to confer upon the boiler-inspecting department the power to order repairs to any part of a locomotive when it is found to be in a condition which it deems unfit for service. Such beneficial action as it has been enabled to exert at present in connection with engine inspection is of a voluntary kind, and, while the report bears testimony to the manner in which railway officials as a rule appreciate this service, there are some who decline in any way to notice its suggestions, even when they concern grave defects, on the ground that the supervision of the department is limited by law to the boiler and not to other parts of the locomotive. The gratifying results brought about by the system of periodical inspection as regards locomotives will, it is to be hoped, lead to the growth of a healthy demand by the American public for the application of similar legislation to all other classes of boilers. If it were applied, the results, we venture to say, would be even more striking than those revealed in the report under notice.

THE INSTITUTE OF METALS.

THE annual general meeting of the Institute of Metals will be held at the Institution of Mechanical Engineers, Storey's Gate, Westminster, S.W., on Tuesday and Wednesday, March 17th and 18th. On the Tuesday, at 3 p.m., there will be a general meeting of members in the hall of the Institution of Mechanical Engineers, when the report of the Council on the work of the past year will be presented by the President, and the newly-elected president, Engineer Vice-Admiral Sir Henry J. Oram, K.C.B., F.R.S., will deliver his inaugural address. In the evening the fifth annual dinner will be held at the Criterion Restaurant, Piccadilly Circus, W. On the Wednesday the members will meet in the hall of the Institution of Mechanical Engineers at 10-30 a.m. and 3 p.m., when a selection of papers will be read and discussed. The following is a list of the papers and reports that are expected to be submitted: (1) First report to the Beilby Research Committee, dealing with the solidification of metals from the liquid state, by C. H. Desch, Ph.D., D.Sc. (2) "Bronze," by J. Dewrance. (3) "Vanadium in Brass: The Effect of Vanadium on the Constitution of Brass containing 50-60 per cent. of Copper," by R. J. Dunn, M.Sc., and O. F. Hudson, M.Sc. (4) "The Quantitative Effect of Rapid Cooling on Binary Alloys" (second paper), by G. H. Gulliver, B.Sc. (5) "Crystal Protomorphs and Amorphous Metal," by Prof. A. K. Huntington, A.R.S.M. (6) First report of the Nomenclature Committee. (7) "The Influence of Nickel on Some Copper-aluminium Alloys," by Prof. A. A. Read, M.Met., F.I.C., and R. H. Greaves, M.Sc. (8) "Muntz Metal: The Correlation of Composition, Structure, Heat Treatment, and Mechanical Properties, &c.," by J. E. Stead, D.Sc., D.Met., F.R.S., and H. G. A. Stedman, A.M.I.E.E. (9) "The Micro-chemistry of Corrosion," part II., by S. Whyte, B.Sc., and C. H. Desch, Ph.D., D.Sc. At a meeting on May 12th, Prof. E. Heyn (Berlin) will deliver the fourth May lecture, his subject being "Internal Strains in Cold Wrought Metals, and Some Troubles Caused Thereby." The lecture will be given at 8 p.m. in the hall of the Institution of Mechanical Engineers. The annual autumn meeting of the Institute will be held at Portsmouth during the second week in September, 1914.

SIEMENS' CONTINUOUS INGOT-HEATING FURNACE.

WE illustrate herewith a design of furnace for heating ingots, billets, blooms, &c., the invention of Mr. F. K. Siemens, 10, Queen Anne's Gate, Westminster, London. The furnace is of the type known as pushing furnaces and in which the ingots to be heated are delivered to the furnace at one end and are fed forwards through a portion of the furnace having a comparatively low temperature to a high-temperature portion or finishing hearth, usually heated by a horseshoe flame or a flame extending across it, where the billets are raised to a temperature suitable for rolling, forging, or other treatment. With this furnace it is claimed that an efficient condition can be readily maintained without necessarily providing large discharge door areas even in the case of pushing furnaces of large capacity and high working temperatures on the finishing hearth which are becoming common. The part of the furnace which is most liable to wear and tear, namely, the finishing hearth, together with its roof and side walls, are made removable and interchangeable.

Fig. 1 is a longitudinal section on line A—A of Fig. 2, which is a sectional plan on line B—B of Fig. 1. The furnace is a regenerative furnace with the brickwork omitted from the

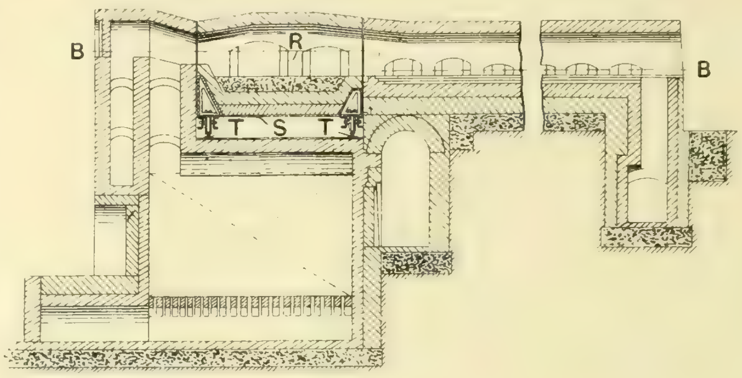


FIG. 1.

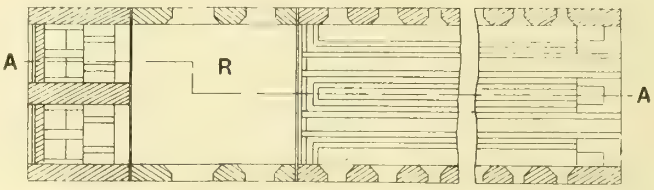


FIG. 2.
SIEMENS' CONTINUOUS INGOT-HEATING FURNACE.

regenerative chambers. The whole of the finishing hearth R, including the roof or arch and side walls, is mounted on a carriage S which runs on rails T laid upon the foundry floor. Should the finishing hearth, or any part thereof, require renewal or repairs, or should access to it be necessary for any other purpose, such as the removal of billets which have become welded together, it is run out on the rails T and replaced by a similar hearth, thereby enabling the furnace to be used practically without interruption. In addition to the greater accessibility for repairing and other purposes, the construction of these furnaces with a removable finishing hearth involves the further advantage that the time required for cooling down the hearth is much less when the hearth is drawn away from the rest of the furnace than when it has to cool in situ. The joints between the stationary parts of the removable finishing hearth are formed in the manner which has been used for a long time in the case of tipping furnaces.

Disastrous Explosion at a Dynamite Factory.—On Friday morning last an explosion occurred at the Ardeer factory of Nobel's Explosives Company, Ltd., resulting in the death of eight men and injury to several others. The official account of the disaster issued by the firm states that "Shortly after 10 o'clock the contents of a building in which blasting explosives are mixed exploded and communicated itself almost immediately thereafter to a small magazine in which there were no workers at the time. The two buildings were completely wrecked, and a good deal of structural damage was done to other buildings. Five men who were employed in the gelatine mixing house lost their lives. In addition to these, three service runners also lost their lives. Some other workers suffered minor injuries. At present it is impossible to say what caused the accident."

BREAKDOWNS OF STATIONARY ENGINES.*

BY MICHAEL LONGRIDGE, VICE-PRESIDENT.

I UNDERSTAND that the subject on which you wish me to discourse is "Breakdowns of Machinery." That is a far larger field than I can well cover, and so I propose to survey one part only—viz., that occupied by stationary steam engines, such as are commonly used for driving mills and factories, and about these there is much more to be said than I can say in the short space of one hour.

Now breakdowns of stationary engines is rather a sensational title for a lecture, and it is possible that some may have come here expecting a more exciting story than I am prepared to tell. That such may not depart entirely unsatisfied I will begin by referring to the bursting of the flywheel of a pair of horizontal compound engines, indicating about 400 i.h.p., and transmitting that power to a weaving shed by a spur flywheel hung upon the crank shaft. Both cylinders had Corliss valves. On the morning of the accident the engine started at 6 a.m. and ran as usual till about 7 a.m., when it began to race. The operatives threw off their looms and ran. The engine-man and another man rushed to the engine house, and with conspicuous bravery made for the stop valve, which, as usual, was placed between the two cylinders in a direct line with the flywheel. Before they could close the valve, possibly before they reached it, the flywheel burst, and both were killed. Some of the flying masses cut the travelling crane in two and unroofed the engine house. Others cut through the wall of the engine house and ploughed a path of destruction into the weaving shed, unfortunately injuring four of the weavers who had been unable to escape. The flywheel arms were snapped off short, at their junctions with the boss, and a large piece was torn out of the boss itself, the pinion was broken, and the second-motion shaft — a heavy shaft, 8½in. in diameter—was dragged from its fixings and bent. The engine foundations were dislocated, and the engines themselves moved bodily from their places. Fortunately, the cranks and connecting rods remained connected, and the cylinders were saved, but all the valve gear was smashed and the bedplate of the condensing engine was badly cracked.

When the wreckage had been cleared away sufficiently to allow access to the engines, I examined them. I found the governor, the wheels which drove it, and the knock-off gear in order. The front steam valve of the high-pressure cylinder was open and the spring in the front end of the dashpot, which should have closed it, was compressed and cemented coil to coil, and to the walls of the dashpot, by a viscous brown cement consisting apparently of baked grease. The spring remained compressed when taken out. If it stuck fast when the engine was running, the steam valve at the front end of the cylinder must have remained open and the racing would be accounted for. In suggesting this as an explanation of the breakdown, however, I should mention that the consolidation of the grease about the dashpot spring may have been due to cold, for, owing to the destruction of the engine house roof and wall, the engines had been exposed to very cold weather for several days before I saw them. The cause of the breakdown, therefore, is uncertain.

Cause of Breakdown.	1881 to 1890.	1891 to 1900.	1901 to 1910.
	Per cent.	Per cent.	Per cent.
(1) Accidents and causes not ascertained....	36	27	29
(2) Negligence or ignorance of owner or attendants	19	22	19
(3) Structural weakness, bad design, workmanship, or material	30	30	21
(4) Old defects, and deterioration by wear and tear	15	21	31
Total	100	100	100

In another mishap of a similar nature the wreck was too complete to leave any clue to the cause. Fortunately, smashes so complete are the exception, not the rule. Of 71 breakdowns in 100 the cause can be discovered. The table herewith shows the number of breakdowns attributable to each of the four groups of causes, as percentages of the total breakdowns during three consecutive periods of ten years.

The classification is not very satisfactory, because it is without clear lines of demarcation. It was begun many years ago and could not afterwards be altered without much labour. But if the figures are not very accurate, their meaning is quite clear. Those in line 1 call for no remark, except that the high percentage in the first decennial period is principally due to want of opportunity for investigation. The constancy of the percentage in line 2 suggests that Board schools have not changed human nature over much; but the reduction in the last column of line 3 awakens hope that the vast sums spent on technical education have not been altogether wasted; and, if we take the figures for each of these ten years separately, hope changes to conviction, for we find the percentage falling more or less regularly from 23 in 1901 to 16 in 1910. If more evidence be wanted, it is given by line 4, which by comparison with lines 2 and 3 reveals how work and age are year by year supplanting ignorance, neglect, bad workmanship, and bad design as causes of breakdowns of steam engines. I do not mean to say that improvement in design only began ten years ago, but it was gradual. The substitution of the principles of mechanics and arithmetic for rule-of-thumb was slow, and the replacement of old engines by new was slower still, so that years elapsed before the effects of the change became appreciable. But if progress was slow, it was effective. When I began to collect statistics 34 years ago, engines running for the most part 50 to 60 hours per week broke down on an average once in 5½ years; now, though speeds and pressures have been doubled, they break down once in 9½ years. That is what we older men have done. Those who are taking our places are expected to do more; and if it will lighten your task to start it with some knowledge of the casualties from which the several parts of steam engines most commonly suffer, I am here to tell you all I can in the time allotted to me.

Valves and Valve Gears.—I begin with valves and valve gears, because at the present time they fail more frequently than other parts of steam engines. About one-third of the total number of breakdowns originate in them. The proportion has nearly doubled in the last 35 years. It has increased concurrently with the use of Corliss and other complicated automatic trip gears, made up of many pieces. Many of those gears are too weak for the abnormal stresses to which all valve gears are occasionally exposed; but a large proportion of the breakages is due to failures of the screws, bolts and keys, by which the parts are held together. Many breakages of valve gears cause little damage, but some have very serious results. Most "runaways" are due to failure of valve gears or governor gears controlling them. Every engine, therefore, ought to have a "knock-off" gear acting on the stop valve or a special runaway valve. Electric gears which can be operated by pressing a button in any part of the works, as well as by the knock-off motion on the engine are the best. Valves intended to be closed by springs should be actuated by gears which will close them if the springs should fail, as seems to have happened in the breakdown I first mentioned. Not a few breakdowns are caused by eccentrics slipping or becoming disconnected from valves, leaving the one or other of the cylinder ports permanently open or closed. When this port is a steam port of a high-pressure cylinder a runaway may follow; when it is an exhaust port the compression curve may run up high enough to blow off the cylinder end. When the inlet to the low-pressure cylinder remains closed, the pressure in the valve chest or receiver may rise sufficiently to burst one or the other. All these things have happened, and the only preventatives I can suggest are large safety valves, ferruled to prevent overloading, not only on the cylinder ends, but on the receivers, or pipes between the cylinders.

Air-pump Motions, Valves and Buckets.—After valve gears the parts which fail most frequently are air pump motions, valves and buckets. They accounted for 20 per cent. of the engine breakdowns 30 years ago. They still account for about 16 per cent., and yet some trouble on the part of engine tenders, and a little thought on the part of engine builders, would enormously diminish the number of mishaps. The cause of half of them is corrosion and neglect. Neglect is almost pardonable when one considers the dark, dirty, inaccessible holes in which air pumps are so often placed. Corrosion is to be expected, and should be circumvented by putting

* Lecture delivered before the Graduates' Association of the Institution of Mechanical Engineers, on February 9th, 1914.

neither bolts, nuts, screws, rings, valves, nor guards inside the pump. There are both vertical and horizontal air pumps on the market which can be made without a single fastening inside. If you must use the old-fashioned vertical pump, put no rings in the bucket; water-sealed buckets need not be tight. I have known two plain buckets, ⅜in. less diameter than the pumps in which they worked, giving 10lbs. vacuum in the cylinder.

Secure the bucket and guard against a collar or cone on the bottom of the rod, by a nut or cotter on top, as in Figs. 1 and 2, instead of tapering the cone downwards and putting the nut below the bucket, as in Fig. 3, to drop off and allow the bucket to fall into the foot box. Slide the foot valve grid into grooves in the foot box, and cast the guard upon the foot box cover, as in Fig. 4, so that there may be no bolt to corrode and break. If the pump be horizontal, the bucket will not be water sealed, and the piston must either be renewed when it has worn down, or fitted with a ring. The piston, being a plain disc, can be screwed and shrunk on to the rod. Do not

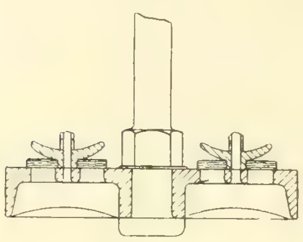


FIG. 1.

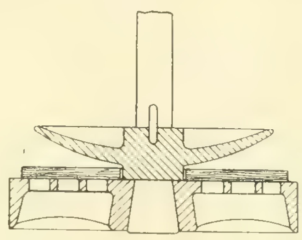


FIG. 2.

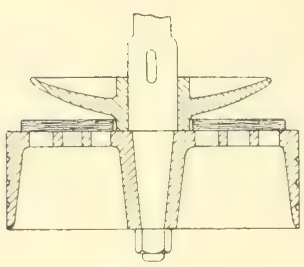


FIG. 3.

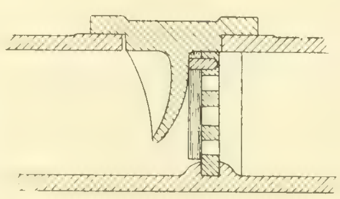


FIG. 4.

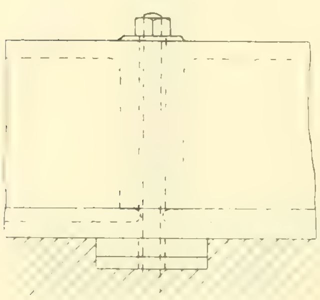


FIG. 5.

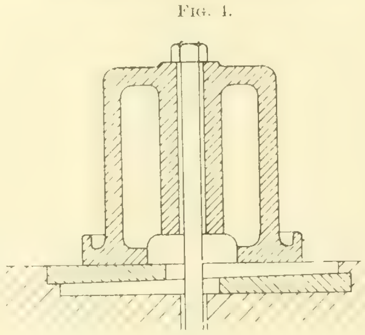


FIG. 6.

use combinations of brass and iron. If the water be at all acid, a brass-sheathed rod will be cut through, where the sheathing ends, as with a knife. Avoid trunk motions. The screw of the eye at the bottom of the trunk will suffer from corrosion, and the pin from grit. Every trunk motion I have had to deal with has broken down at least once. Finally, pay great attention to all fastenings; put the air pump in a light, accessible place, and if there be any doubt about the free flow of the water from the hot well by gravitation, make the motion fit for a pressure of at least 50lbs. per square inch on the bucket.

Bed Plates. — Breakages of engine frames and bed plates can be dismissed with a very few words, because by far the largest number are caused by the pounding of the engines, or by wringing up holding-down bolts, after the seats below have been softened by oil. It is true that, with modern systems of lubrication and oil recovery, very little oil should reach the seat, but it is equally true that the modern practice of setting down an unplaned bed plate in a rough lump of concrete, packing it level with any bits of iron that may be handy, and grouting it with cement, provides so little material to resist the oil that the grouting ceases to give adequate support even sooner than did the old ashlar seats with gallons of oil poured over them each week. The consequence is that breakages of frames, bed plates, and the like, still bear as large a proportion to the total breakdowns as in the early 'eighties, namely, about 7 per cent. It is quite easy to keep engine seats free from oil, and dry. All frames and bed plates should have channels round the feet, as in Fig. 6, troughs under the ends of all bearings, or, when there is only a top and bottom brass, shields like

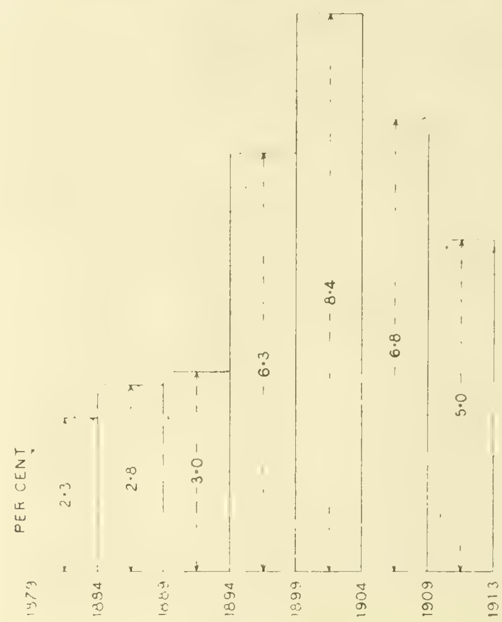


FIG. 7.

those on the bearings for the shafts of dynamos and motors. The bed plates of vertical engines of the marine type should have the bottoms of the crank pits cast with them.

Where a bed plate is to rest on ashlar, it should be planed on the underside, and rubbed to a perfect fit upon the dressed surface of the stone. When it is to rest on concrete, the bottom surface, which is to be supported by the cement grouting, should be as wide as possible, instead of a strip a few inches wide along each side; and holes should be arranged at intervals for running the cement into the space between it and the concrete seat. In my opinion it is best to plane the underside at each holding-down bolt, and level the bed plate

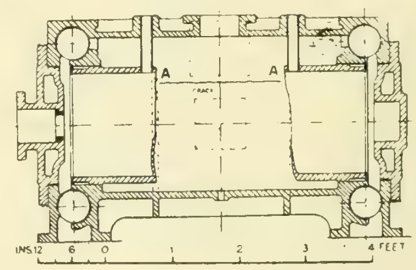


FIG. 8.

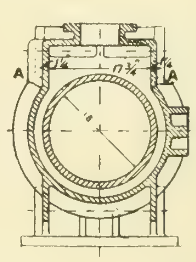


FIG. 9.

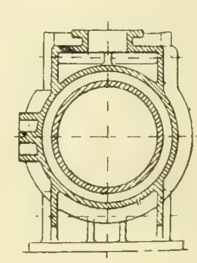


FIG. 10.

upon a pair of broad machined folding wedges at each bolt hole, as in Figs. 5 and 6.

Cylinders should not be placed on concrete, but on iron frames or plating, according to their shape. This plating should have holes for running cement between it and the concrete seat, and there should be raised rims round these holes, round all openings for pipes, and round the edges, to retain oil and water; also machined facings for the cylinder feet to

stand on, so that they may slide when the cylinders expand. Horizontal engines should be firmly held to the seat at the crank end, but the cylinder end should be free to slide. Never tighten a holding-down bolt till the superincumbent weight has been lifted from the bed plate, and the space below it, if there be any, carefully packed.

Cylinders. — In old days breakages of cylinders were generally due to water or stray piston bolts; now the majority are caused by water or structural weakness. The diagram, Fig. 7, shows plainly what has happened. The abscissæ represent successive periods of five years from 1879 to 1913, the ordinates the breakages of cylinders, as percentages of the total number of breakdowns, in each quinquennial period. The year 1883 may be considered as about the end of the old time, when 80lbs. was a high pressure, and a tallow kettle simmered on the cylinder. About 1890 steam of 160lbs. pressure began to be used in mills, and many old cylinders, reduced in diameter by liners, were supplied with it regardless of weakness of ends and valve chests. Also many of the new cylinders made about that time were too weak. The curve shows how breakages increased, and subsequently decreased as the new conditions were met by improved designs.

Before referring to some of the faults of design which provoke fracture, I would like to remind designers of cylinders and other parts that deformation, or strain, induces stress. It is often an advantage to consider what deformation would occur in the thing they may be designing if it were made of india-rubber. Figs. 8 and 9 show a cylinder made in 1894 for a pressure of 120lbs. per square inch. It worked for eight years at that pressure, then for 18 months at 140lbs., and finally for six months at 160lbs., when the two longitudinal cracks A A, Figs. 8 and 9, were found. Regarding the cylinder as made of india-rubber, it would be seen at once that the two sides of the upper part of the jacket (Fig. 9) would be forced outwards, and bending would occur just where the cracks appeared. Even if the outer cylinder were complete, as in Fig. 10, the steam passage would be a source of weakness, because its bottom surface, having the same pressure on both sides, would flatten out and allow the same kind of deformation as before. The flat top of the steam passage (Fig. 9) was also weak, and would probably have cracked along its longest edges in course of time, for the stress calculated by the formula for flat surfaces: —

$$f = p \times \frac{b^2}{2\,t^2} \times \frac{l^4}{l^4 + b^4}$$

given in Unwin's "Machine Design" was 16,000 per square inch. In good designs I have found f to lie between 3,000lbs. and 8,000lbs. The wide variation is not surprising when one considers how much the strength of castings is affected by shape and crystallisation during cooling. In dealing with castings experience is the only safe guide, though for purpose of comparison a formula may be useful as a rough criterion.

Fig. 11 shows sectional views of the high-pressure cylinder of a triple-expansion engine, made five or six years later, for a boiler pressure of 160lbs., and a pressure of 70lbs. in the receiver between it and the I.P. cylinder. Soon after it was set to work it cracked through the bars across the ports A, and then from the corners B of the ports. It was replaced by another of the same design, which quickly failed in the same way. Here there was a load upon the end of 92 tons during admission and 52 tons during exhaust. If the cylinder had been rigid and the load distributed uniformly over the cross-section of the metal, the stress would nowhere have been excessive; but with a cylinder of india-rubber it is easy to see how a large part of the load would be concentrated on the bars across the ports, and how, on their failure, the deformation of the end would intensify the stresses at the corners of the ports. Also deformation of the barrel from a circular to an oval cylinder would be caused by the external pressure on the top and bottom, and the absence of an equal external pressure on the sides. This deformation is sometimes sufficient to make well-fitting pistons seize.

Finally, passages cast round cylinders, whether for live steam, as in these figures, or for exhaust, frequently originate circumferential cracks in the barrel, owing to the unequal expansion of the metal inside and outside them. They are also likely to cause sponginess where the walls join on to the barrel. The design is not one to be copied, and I cannot but suspect that if the draughtsman had kept the india rubber model in mind when he was drawing it, these cylinders would never have been cast.

The usual way of strengthening the ends of cylinders is to lengthen the distance between the ports and the end flanges, and then to lengthen the spigots on the cylinder covers, to fill the increased clearance spaces. Unfortunately the clearance surface at each end of the cylinder is thereby increased by two rings, each equal in area to the circumference of the cylinder multiplied by the length of the spigot—rather an important disadvantage when saturated steam is to be used and guarantees of steam consumption are required. Of course, it is possible to suppress the surface by making the spigot fit the cylinder, but then it is extremely difficult to get the cover off; or by making the joint at the surface of the spigot next the piston, but that may be as dangerous to the cylinder and cover flanges as a ring of jointing material placed entirely inside the bolt circle, unless special precautions, which I cannot now describe, be taken. The practical alternative seems to be to make the space so narrow that, when it is filled with water, the surface of the water presented to the steam in the cylinder will be so small that the condensation and evaporation will be

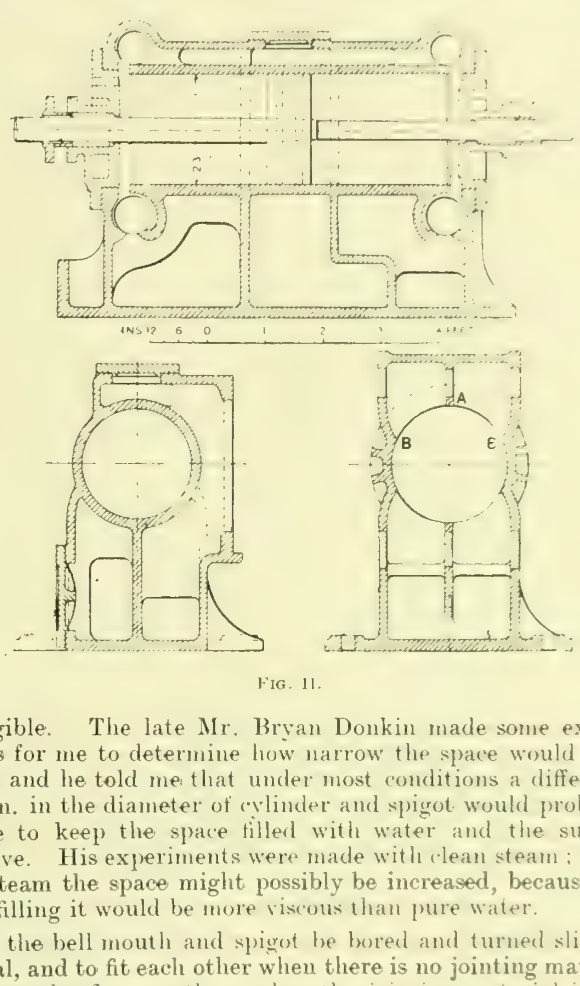


FIG. 11.

negligible. The late Mr. Bryan Donkin made some experiments for me to determine how narrow the space would have to be, and he told me that under most conditions a difference of $\frac{1}{16}$in. in the diameter of cylinder and spigot would probably suffice to keep the space filled with water and the surface inactive. His experiments were made with clean steam; with oily steam the space might possibly be increased, because the fluid filling it would be more viscous than pure water.

If the bell mouth and spigot be bored and turned slightly conical, and to fit each other when there is no jointing material between the flanges, then, when the jointing material is put in, the water space will be very narrow, but will widen rapidly as the cover is being drawn off. When the bell mouth is very short, deformation and local stress at the corners of the ports may be reduced by bolting a deep cover, like a short cylinder with its two flanges tied together by ribs between the bolt holes, to the cylinder flanges. The difficulty of designing cylinders for high pressures and temperatures is much enhanced by attempting to combine valve chest, steam and exhaust passages, and cylinder in a single casting. It is far better to make cylinders plain tubes, or plain tubes with nozzles near the ends, and to carry the valves in suitable gable ends, cylinder covers, or valve chests bolted to the flanges on the barrels. The arrangement allows the barrel to be made of hard metal, giving an index number of about 40 when tested by Shore's scleroscope; while the more complicated castings, containing barrel, valve chests, and passages, cannot be made with metal giving a higher number than about 36. Moreover, the distortions produced by temperature, and by

the growth of grey cast irons under temperatures as low as 500 Fah., imperatively demand the very simplest forms.

Damage by Water.—Leaving cylinder design, I now wish to say a few words about breakdowns from water. Water is seldom carried over from boilers in sufficient quantity to cause damage when steam pipes are properly laid, as shown in Figs. 12 and 13, with a continuous fall from the boiler junction valve to a well pipe or separator near the cylinder, and a continuous rise from the separator to the engine stop valve, which should be at the highest point of the pipe, and as near to the cylinder as possible. Pipes with vertical bends (Fig. 14) are

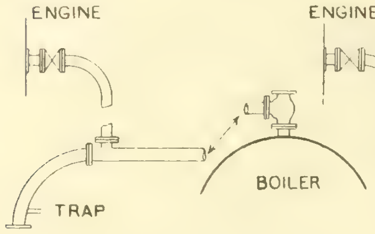


FIG. 12.

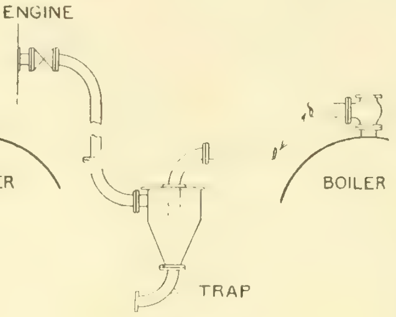


FIG. 13.

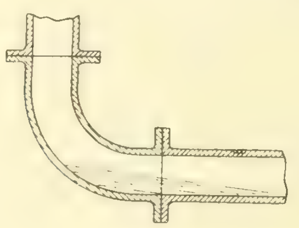


FIG. 14.

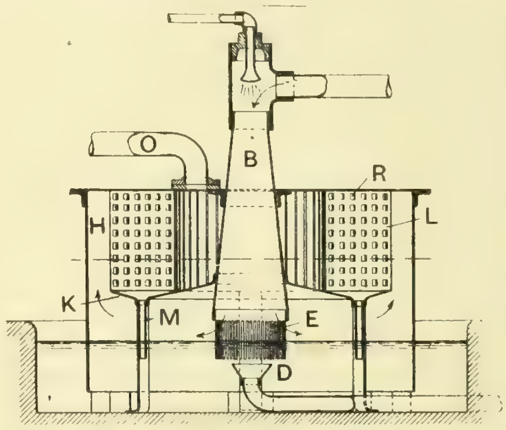
apt to harbour water when only a light breeze of steam is blowing through them, and this water is carried forward in gulps when the breeze becomes a hurricane. But even these gulps seldom do damage, except when they get into the upper ends of vertical cylinders, the exhaust ports of which are shut before the end of the up stroke, or into horizontal cylinders with the exhaust ports on the top. Generally the water causing breakdowns comes from jet condensers, when an engine is running slowly, and the injection cock has not been shut, or the vacuum destroyed. The flow into a jet condenser depends upon the vacuum therein, the flow out of it upon the speed of the air pump; and it may easily happen, when an air pump is running slowly, that more water may enter the condenser than the air pump can discharge, in which case the excess first fills the exhaust pipe and then runs into the cylinder. For this reason, when the air pump is driven by the main engine, the vacuum should always be destroyed by letting air into the condenser before beginning to shut off steam; and when it is driven by an independent engine this engine should be started before, and stopped after, the main engine. It is often extremely interesting to discover how water has got into a cylinder, but time will not permit of going into this point now in further detail.

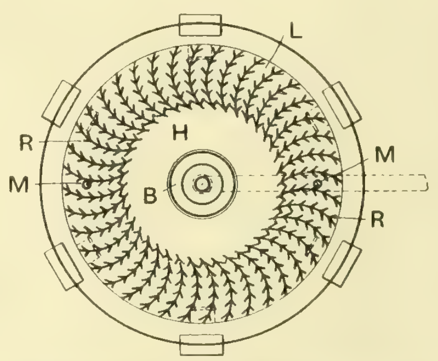
(To be continued.)

WOLLASTON'S APPARATUS FOR COOLING, CLEANING, AND DRYING GASES.

THE accompanying illustrations show an apparatus for cooling, washing, and drying gases of the kind in which the gas is treated with cooling and washing liquid in the form of jets or spray in a vertical chamber or column which diverges towards the base and delivers on to the surface of liquid in a lute or receptacle below. The arrangement, which is the invention of Mr. T. R. Wollaston, 26, Corporation Street, Manchester, is intended principally for cooling and washing the gases delivered from retorts, coke ovens, furnaces, and when necessary for subsequently scrubbing and drying the gas after washing.

Referring to the illustrations, hot and impure gas enters at the top of a central vertical chamber B conical in shape, and at or near the apex are introduced in a downward direction finely divided liquid sprays under considerable head. As the gas travels down the increasing thoroughfare of the chamber B its velocity is reduced, but heavy entrained particles by reason of their momentum retain some of their initial velocity and tend to "race" the gas and to fall to the bottom into a lute. The sprays from above help in combining with entrained matter and in carrying it downwards to the lute. The lower edge of the coned chamber B terminates some small distance above the level in the lute but is provided with what may be described as a comb edging E, the prongs of the comb being fluted so that their points may dip below the surface of liquid in the lute and form suitable channels for draining into the lute, while the spaces between the prongs allow the cooled and washed gas to escape radially. Surrounding the central coned chamber is a cylindrical shell with cover which forms an enclosed annular chamber H of considerable size around the central chamber B and the lower edge of which dips into the lute. On a stage K within the annular chamber is mounted some form of filtering or drying device, for example, a bed of fibrous or granular material in a cage. Or alternatively a dryer consisting of radially disposed and closely spaced thin metallic plates L. The stage carrying the drying device is dished and provided with drop pipes M for draining, which dip into the lute. The radial plates may be formed of corrugated metallic sheets mounted with corrugations arranged vertically, and with wings R punched out by a blunt punch, or they may be plain non-corrugated plates with wings R punched in a similar manner, or the plates may be punched and curved and disposed in plan in the well-known





WOLLASTON'S APPARATUS FOR COOLING, CLEANING, AND DRYING GASES.

manner of the blades of a pressure fan or blower, so as to cause the gases passing between them to take an indirect course as shown.

In one arrangement of the apparatus the gases pass from the "comb" shaped lower edge of the central chamber radially outwards under the supporting stage, and then flow upwards and radially inwards through the drying device, finding final exit through an outlet branch O in the cover of the outer casing. In another arrangement the gases pass from the "combed" lower edge E of the central chamber B directly upwards and then turn outwards to pass radially through the drying device, finding final exit through an outlet branch at or near the periphery.

FENCING AND OTHER SAFETY PRECAUTIONS FOR TRANSMISSION MACHINERY.*

(Concluded from page 168.)

(Concluded from page 168.)

Belt-perches.—These safety appliances are closely associated with the fencing of belts. Where machines are worked intermittently, it is a common practice in many factories, after the use of a machine, to throw the driving belt off the shaft pulley until the machine is again required, in order to economise power and to save wear and tear of the belt and pulleys. A belt may also slip off the driving pulley accidentally or may be thrown off intentionally for the purpose of repairs. It is a dangerous practice, however, to allow a belt under such circumstances to rest on a revolving shaft, owing to the liability of the shaft to seize the belt and wind it up. Accidents, due to falls of shafting and parts of machinery, have often occurred from such a cause. Many fatalities and serious accidents have also happened to persons on taking hold of a belt resting loosely on a revolving shaft; these have suddenly been carried up to the shafting owing to increase of frictional resistance between the belt and the shaft.

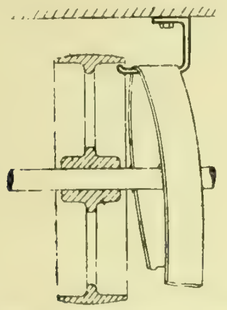


Fig. 16.—Simple Belt-perch.

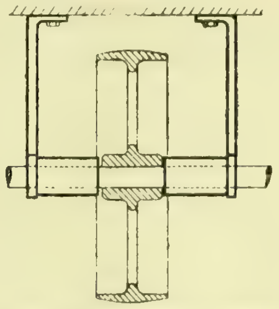


Fig. 17.—Sleeve Belt-perch.

Provision must be made in all cases to keep loose belts out of contact with revolving shafts. There is no danger if the shaft is fenced by a sleeve of metal or other material. In other cases some type of belt-hook or belt-perch must be used, and various forms are available. The simplest (Fig. 16) consists of a strong hook fixed adjacent to the driving pulley, with the horizontal portion somewhat longer than the width of the belt and the end turned up under the pulley rim. Another type, consisting of a sheet-iron sleeve or trough riveted to a bracket, is shown in Fig. 17. A belt-perch may be fixed on each side of a pulley if it is desired to displace the belt on either side. For horizontal belts, the belt-perch may consist of a simple bracket provided with two pegs as in Fig. 18, fixed near the driving pulley and shaft; similar brackets may be fixed at intervals to support a long stretch of horizontal displaced belting. A better type where belt-poles are used to replace belts on pulleys is shown in Fig. 19, consisting of four or more parallel pegs with turned-up ends, bolted to a curved bracket fixed eccentrically near the pulley. The design of the bracket can easily be adapted to suit different positions and directions of the driving belts (Fig. 20). If a pulley is situated close to a bearing, or if two pulleys are close together, modified perches (Figs. 21 and 22) should be fixed to prevent the belt falling between pulley and bearing or between the pulleys — a frequent cause of accidents and damage to the mill-gearing and machinery. Some form of belt-perch should be used in preference to tying up a belt to the ceiling above the shafting, an operation which often has placed the worker in a position near unfenced shafting and in many instances has led to fatalities and serious injuries. Whenever any belt repairs are necessary while the shafting is in motion, the belt should never be allowed to come in contact with the shaft, but should rest either on the sleeve fencing the shaft or on a belt-perch. Portable perches consisting of an inverted trough fixed to the end of a belt-pole are sometimes used, but fixed perches are more satisfactory whenever these are practicable.

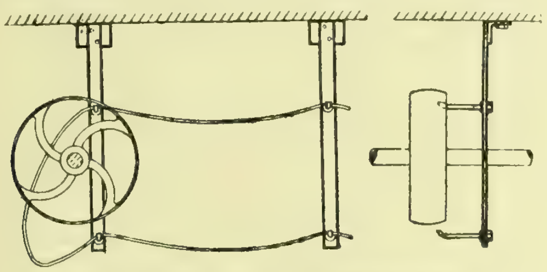


Fig. 18.—Belt-perch for Horizontal Belts.

Belt-shippers. — A number of appliances, both portable and fixed, have been devised for replacing belts on pulleys from the floor level in cases where the effect of slowing down the transmission machinery would lead to damage and loss of material, especially where continuous processes are carried on. For belts not exceedings 3in. wide, an ordinary belt-pole may be used. This is a strong, light pole about 1½in. diam., carrying at its upper end a wrought-iron pin at right angles to the axle of the pole. Generally the pin forms part of a forged tee-piece driven into the end of the pole and secured by a ferrule. The length of the pole should not be less than the height of the shafting above the floor level. There is always risk of accident with a short pole as the lower end is liable to be driven forcibly towards the workman if the pin is caught between the pulley and belt or in the pulley arms. A rigid belt-pole is unsuitable in many cases, and its use may be considerably limited by position, size, length, tension, or direction of the belts, or by such obstructions as pillars, beams, and walls. Various types of jointed and flexible belt-poles have been devised to overcome these difficulties; a flexible pole is probably safer to handle than one of the rigid type. Another improvement consists in making the pin revolve on a friction roller instead of being rigidly fixed. In most cases, belt-poles are easier to handle when belt-perches of types consisting of parallel bars or a curved metal plate are fixed adjacent to the pulley rims. (Fig. 22). With such a perch it is said that a belt 9in. wide can be replaced on its driving pulley by means of an ordinary belt-pole. When the belts are too heavy or the shafting too high to allow the use of a belt-pole, mechanical belt-shippers enable the belt to be replaced on the driving pulleys from the floor level with perfect safety, without stopping or slowing the transmission machinery.

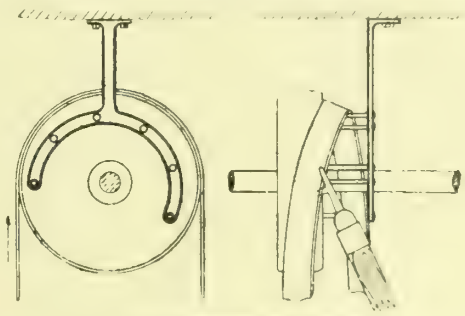


Fig. 19. -Improved Belt perch.

The earliest type was invented by M. Boudoin, of St. Sauveur-Luxeuil, in 1871, and is said to be in general use throughout the factories in Alsace. This (Fig. 23) consists of an arm or board with bevelled edge, bolted to a socket which is free to rotate on a fixed sleeve encircling the driving shaft. The sleeve is attached by a bracket to some convenient support adjacent to the pulley. Both socket and sleeve are made in halves screwed together. The fit between sleeve and socket may be adjusted by tightening or slackening the socket screws. The driving shaft rotates freely within the sleeve. The appliance thus forms a belt-perch upon which the belt rests when thrown off the driving pulley, and each pulley must be fitted with one of these appliances. To replace a belt the wooden arm and socket are turned through an arc of a circle by means of a pole fitted with a hook which engages a small knob near the lower end of the arm; the bevelled edge of the arm picks up the belt, allows it to slide on the pulley at the point of intake, and prevents it slipping off the pulley as it travels round the rim.

The type of belt-shipper adopted by the Italian Association for Prevention of Industrial Accidents closely resembles

* From Home Office report on "Fencing and Safety Precautions for Transmission Machinery," by W. Sydney Smith, H.M. Inspector for Dangerous Trades.

the above, but the lower half of the socket is provided with two arms inclined at an angle of 60° towards each other and connected at the bevelled extremities by a metal band bent to the same curvature as the pulley rim (Fig. 24).

There is also a portable Boudoin belt-shipper which may be used for shafts and pulleys varying somewhat in diameter. The sleeve which encircles the driving shafts is made in halves, and the lower half is provided with a screw which engages a nut at the end of the belt-pole to which the apparatus is affixed; the movement of this half is constrained except in a vertical direction. The sleeve can thus be readily placed over a shaft within reach of the pole, and the halves can be brought together by simply rotating the belt-pole. The wooden arms attached to the socket are provided with slots which allow adjustment for pulleys of different diameters (Fig. 25). The apparatus is placed adjacent to the pulley and held in position while the belt is replaced in the usual manner by rotating the arms with a hook attached to a pole.

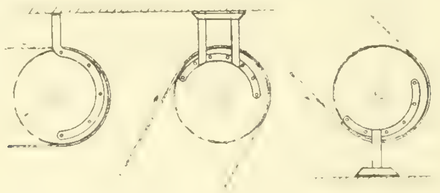


FIG. 20.—IMPROVED BELT-PERCHES FOR DIFFERENT POSITIONS OF BELTS.

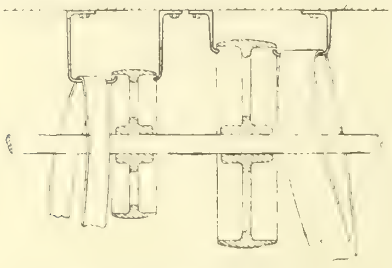


FIG 21.—SIMPLE BELT-PERCHES.

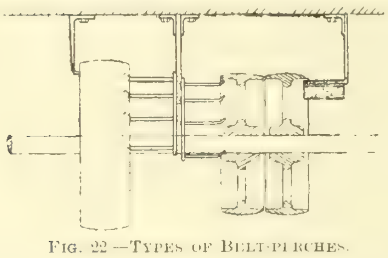


FIG. 22.—TYPES OF BELT-PERCHES.

The Brancher belt-shipper (Fig. 26) is similar to that of Boudoin, but the supporting bracket and sleeve are omitted; the socket carrying the wooden arm is suspended on the line shaft close to the pulley, and lateral movement is prevented by a pair of collars screwed to the shaft by countersunk set-screws. The socket is made in halves and the upper half is provided with sheet-metal wings which form a belt-perch and prevent the belt coming in contact with the bare shaft; it contains small hard wood rollers which rotate in thick lubricant, thereby preventing any tendency of the metal surfaces to seize. The Brancher apparatus and other types may be actuated by means of cords or hand-chains instead of a pole if a light pulley with a V-shaped rim is attached to the socket carrying the belt-shipping arm. Poles are often missing when wanted and the worker is then tempted to replace a belt by hand. No excuse can be offered in case of failure to use the appliance if it is self-contained and complete with operating cords or chains.

A number of other types have been devised by Continental inventors. These consist of various arrangements of metal arms adjoining the pulley and form a belt-perch which carries the unshipped belt; the arms are generally rotated by means of hand chains or cords (Piat-Forest, Fouvez, Hofman, &c.). In others the belt-perch consists of small rollers on parallel pegs fixed at the side of the pulley and arranged slightly eccentrically to the rim; the belt is pushed from the rollers to the pulley by a series of forked levers which are operated simultaneously by suitable links and a hand rope (Heurtier-Piat), or the belt-perch is moved towards the pulley by means of a rack and pinion operated by means of a cord and pulley (Rieger). In the latter device conical rollers are fitted on the pegs of the belt-perch to facilitate mounting of the belt. Mechanical belt shippers are often used in connection with a fast pulley instead of a combination of fast and loose pulleys with striking gear. An English type of belt-shipper is shown in Fig. 27.

Considerable ingenuity has also been exercised in devising appliances for moving belts from step to step of cone pulleys. Such belts are generally moved by hand and the workers become exceedingly expert, but records of belt accidents show that numerous traps and crushes of the hands are caused by manipulating the driving belts of cone pulleys on lathes, drills, and other machine tools. The devices of Duparque, Hirsch, Berand, and Bamag have found application in many Continental works, and examples are found in some of the engineering factories in this country.

Immediate Stoppage of Transmission Machinery.—Provision should be made in all factories for bringing the shafting quickly to rest in case of breakdown of machinery or accidents to workers from transmission machinery. In old installations electric bells are often considered sufficient for signalling between workrooms and engine houses, but are often inadequate in case of mishap or accident on account of inevitable interval between the accident, receipt of signal, and stoppage of the prime-mover. Where steam engines are used, more efficient devices are those whereby the engine stop-valve can be directly actuated from any floor or room in a factory, by means of electric push-buttons fixed in convenient positions. Horns, whistles, electric bells, and similar appliances are, however, most useful as a means of communication between beltmen or greasers and the engineer when the former are engaged on repair of belts or other work of maintenance in connection with transmission machinery. Exchange of signals should always be made whenever the engine and transmission machinery is required to be stopped, moved, or restarted in connection with such work.

With electric motors for driving the main shafting it is comparatively simple to arrange, in convenient positions of the workroom, push-buttons to actuate the main switch and stop the motor. A powerful electro-magnetic block brake may also be fitted on the line shaft to bring the transmission machinery quickly to rest. For new installations in factories provided with electric power supply an electric motor for each machine or small group of machines is the best solution of the problem for immediate stoppage, and possesses many advantages, as lines of shafting, many belts and pulleys, and other dangerous elements are eliminated, often with economy in running costs.

If mechanical appliances such as clutches are used, the means for disengaging the transmission machinery should be within convenient reach of the workers. Clutches may be worked by means of a hand lever, a hand wheel and screw, or a chain wheel and rack. Electric arrangements, consisting of an electro-magnet in combination with a powerful spring, have been devised for actuating the disengaging lever of a clutch by means of push-buttons from any number of points in the electric circuit.

Oiling and Cleaning.—Such necessary work as oiling and cleaning should be done only by trained and authorised persons; and the oiling of shafting only during stoppage of the transmission machinery, or (if this is not possible owing to special circumstances or the requirements of the manufacturing processes) during slow running of the line shafts, unless the transmission machinery is so fenced as to prevent accidental contact with moving parts. Oil cups or lubricators should be fitted on all shaft bearings unless these are of a self-lubricating type. Oiling is unnecessary during motion of the shafting if needle lubricators or wick lubricators are provided. The flow of oil in a needle lubricator ceases when the shaft stops, and hence these are more economical than wick lubricators, which allow loss of oil when the shaft is stopped; moreover the wick may become blocked by dirt unless care is taken as to maintenance.

In self-lubricating bearings the supply of oil or grease will last for weeks or months with little attention, and hence the risk of accident to enginemen and greasers is reduced to

a minimum. There are various types of these bearings; in ring bearings one or more metal rings hang on the shaft journal within the bearing, dip into an oil reservoir and convey the oil to the shaft when in motion; in roller bearings and ball bearings friction is reduced by a ring of rollers or balls, and a small supply of oil will last for a month or longer; for heavily-loaded shafts, properly designed bearings, fitted with grease cups filled with fat, allow the shafting to run for prolonged periods without attention.

Lubrication of loose pulleys is not always easy, and if a loose pulley seizes a shaft from want of oil, the machinery may unexpectedly be set in motion and accidents result. The loose pulley is sometimes made slightly less in diameter than the fast pulley in order to lessen the belt tension. Needle lubricators, and lubricators of the Stauffer type, or fitted with a piston, and filled with solid grease, are sometimes used. The pulley may ride on a recessed sleeve, secured to the shaft, and filled with solid lubricant which can reach the inner revolving surface of the pulley boss through holes in the sleeve. Additional means of safety against seizing or unexpected wear of the shaft may be secured by allowing the loose pulley to run on a metal sleeve forming an extension of the pedestal bearing or on a separate fixed shaft in line with the axis of the countershaft or the live spindle of the machine.

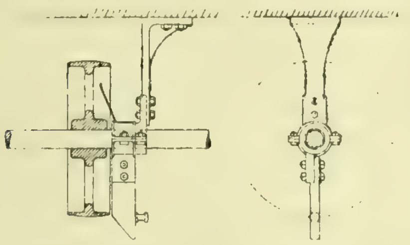


Fig. 23.—Belt-shipper (Boudoin Type).

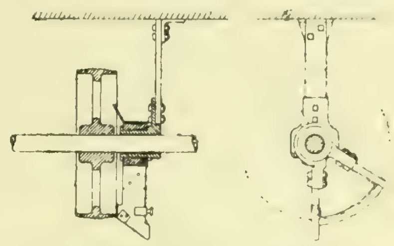


Fig. 24.—Belt-shipper (Italian Type).

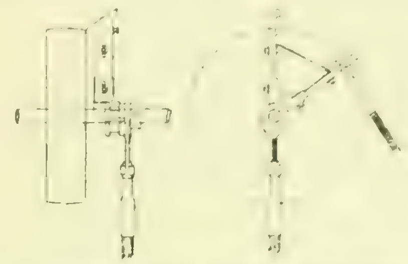


Fig. 25.—Portable Boudoin Belt-shipper.

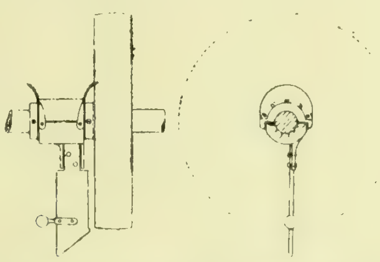


Fig. 26.—Belt-shipper (Brancher Type).

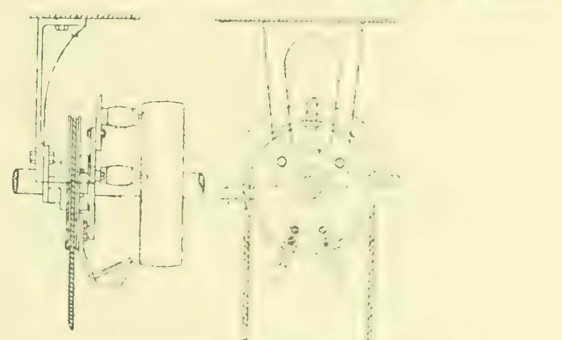


Fig. 27.—Safety Belt-shipper (Cowley's Patent).

Cleaning and polishing of shafting in motion should never be done with cotton waste, rags, or emery cloth held in the hand. Proper appliances should be used, such as long-handled brushes, hooks wrapped round with cord, or special clamps with the jaws covered with leather or emery cloth. These can generally be manipulated from the floor level. Rings of metal or leather which hang loosely on the shaft are to be found in some factories. These travel to and fro along the shaft and effectively clean it. They are largely adopted abroad. Many accidents occur between belts and pulleys in motion to workers engaged in treating belts with various compositions to keep them pliant, or in applying resin to slack belts to make them grip the pulleys better. This is a dangerous practice which should not be allowed unless the transmission machinery is stopped or moved slowly. With a shaft speed of not more than 6 revs. per minute there should be little danger.

Ladders for Transmission Machinery.—Suitable non-skid devices are necessary for all ladders used in factories, especially in connection with transmission machinery for manipulating belts, oiling bearings, and other work of maintenance. Shafting ladders are generally fitted with hooks at the upper end, large enough to rest on the shaft; the hooks should be bound with cord. Close-fitting clothes should be worn by every person employed on or about transmission machinery, and even so there is always risk of accident to the worker, when standing on a ladder reared against shafting, if a torn garment comes in contact with a revolving shaft. The risk may be reduced by removing some of the top rungs of the ladder, or by filling in the spaces between the top rungs with wood or sheet metal, or by replacing the ordinary ladder hooks with a piece of bent sheet iron of suitable length to form a protecting cap over the shaft which would be temporarily fenced as soon as the ladder is placed in position. Safety attachments have been devised for shafting ladders, which are so arranged (either by mechanical or electrical devices in combination with a clutch lever or electric switch) as to cut off the power when the ladder is removed from the place where it must be kept, and the transmission machinery is brought to rest before the ladder can be reared against the shafting. Such an arrangement, however, requires a special ladder for each unit of shafting.

Many appliances have been devised for preventing slipping of the foot of the ladder. Iron spikes attached to the bottom of the ladder are common, but these are dangerous where persons are accustomed to work with bare feet. Generally speaking, the form and material of the non-skid device should depend on the kind of floor; iron-shod feet are unsuitable for hard floors such as iron plates, flagstones, brick, tiles, or concrete unless the surface is grooved; in such cases leather or india-rubber is more satisfactory, though unsuitable for greasy floors. Iron spikes, except as above mentioned, or cast-iron swivel shoes, can be used on soft floors such as wood. Where a ladder is required to be reared at different inclinations swivel feet are the most satisfactory.

N.E. Coast Institution of Engineers' Endowment Fund.—The North-east Coast Institution of Engineers and Shipbuilders, which was founded 30 years ago for the study and advancement of the science of engineering and shipbuilding and has now a membership of 1,200, is making an appeal for the formation of an endowment fund of £25,000. A nucleus of such a fund has already been subscribed to by the president (Sir Charles Parsons), members of the Council, and others, the sum of £3,879 having been promised. While the institution has, by its meetings and the publication of its proceedings, been of great service in disseminating knowledge among those engaged in engineering and shipbuilding, and by means of its Graduate Section and its scholarships done much educational work of value among the junior members of these professions, it has not been possible to accomplish all that is within its province, by reason of its limited income. In proportion to its membership, the income of the Institution, as compared with other similar societies, is inadequate for the fulfilment of its objects. Hence the effort to establish an endowment fund. Those desirous of helping the fund should communicate with the Secretary, Bolbec Hall, Westgate Road, Newcastle-on-Tyne.

THE CLINKERING OF COAL AND ITS COMPOSITION.*

BY OSCAR W. PALMENBERG.

One of the most troublesome features in the combustion of coal is that due to the production of clinker. This influences the rate of combustion and the cost of maintenance, especially where automatic stokers are in use. A coal may clinker so readily under certain conditions that it becomes unfit for use irrespective of its fuel value. It is therefore of the greatest importance to know whether a coal will clinker under the conditions for which it is required. When coal is burned under a boiler for the production of steam it is especially important to know whether the ash will clinker and at what temperature. The production of clinker, as is well known, is due to the fact that the ash of the coal, which is the liberated mineral matter, is exposed to a temperature sufficient to fuse it, causing it to form a viscous mass which will flow and form cakes and thereby clog up the spaces between the burning particles of coal or coke. The mass of fused material offers resistance to the flow of air and robs the coal of the necessary oxygen to support combustion. If the draught cannot be increased to overcome this resistance the rate of combustion is diminished, other things being equal, in proportion to the amount of clinker formed. To determine whether a coal will clinker, that is, whether it has an ash which will fuse at a low temperature, has been undertaken in several ways, and many have been of the opinion that an analysis of the ash or the iron in the ash, or the sulphur in the coal will furnish the explanation.

Table I.—*Analyses showing the Composition of the Ash of Bituminous and Semi-Bituminous Coals, arranged in the order of the Fusing Temperature of the Ash.*

No.	Fusing temperature	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	K_2O, SO_3, Na_2O, CO_2	Sulphur in the coal	Ash in the coal
1	2,700	51·93	4·81	36·82	3·84	1·00	1·60	·51	5·15
2	2,615	44·74	14·14	36·91	2·18	·41	4·85	1·46	7·88
3	2,400	40·61	22·26	32·94	1·77	·51	1·91	2·06	9·70
4	2,600	48·83	6·28	42·62	1·64	·30	3·90	1·01	9·15
5	2,600	54·18	7·29	34·53	3·01	·47	·52	·90	6·41
6	2.372	30·07	39·88	25·31	2·63	·39	1·71	2·41	8·96
7	2,309	47·94	17·95	28·47	4·17	·51	·96	2·11	11·04
8	2,300	46·40	13·84	35·30	3·58	·31	·57	1·80	13·51
9	2,300	30·90	35·13	31·14	2·00	·52	·31	2·13	6·25
10	2,246	35·48	30·67	30·73	2·10	·44	·28	2·17	7·90
11	2,180	29·37	38·75	29·52	1·57	·37	·44	3·97	10·60

No.	Per cent.	Deg. Fah.
2	14·14 iron oxide	2,615 fusing temperature.
8	13·84 ,,	2,300 ,, ,,
6	39·88 ,,	2,372 ,, ,,
11	38·75 ,,	2,180 ,, ,,

No.	Deg. Fah.	Per cent.
7	2,309 fusing temperature	17·95 iron oxide.
8	2,300 ,, ,,	13·84 ,,
9	2,300 ,, ,,	35·13 ,,
3	2,400 ,, ,,	22·26 ,,
6	2,372 ,, ,,	39·88 ,,

To show that there is no relation between the clinkering quality of a coal and the sulphur or iron content, the writer has made this investigation, and the following analyses of the ash, together with the fusing temperature determinations on a wide range of coals, will readily show that no conclusion can be obtained from a chemical analysis. The ash of coal is composed mainly of silica (SiO_2), iron oxide (Fe_2O_3), aluminium oxide (Al_2O_3), calcium oxide (CaO), magnesium oxide (MgO), sodium oxide (Na_2O), potassium oxide (K_2O), carbonates (CO_2), sulphates (SO_3) and small amounts of phosphates. Since all coals, but particularly soft coals, consist of a mixture of pure coal substance and pyrites, bone, slate, fireclay, &c., these elements will be present in a variable proportion, depending upon the nature of the coal vein and the method and care by which the coal is extracted from the ground. In making an analysis, therefore, of a coal sample representing a mixture of all these materials a definite percentage of the component parts of the ash may be obtained, but this analysis does not tell us how much pyrites, bone, slate, fireclay, &c., is present. It is therefore apparently impossible to judge from this analysis whether the ash will have a high or low fusing temperature. It is true that the pyrites will fuse at a lower temperature than the slate, but since both may contain iron, the analysis does not indicate a method of arriving at a conclusion to show the fusibility of the ash due to the iron content. The problem offered is very similar to that of trying to determine a formula by which the heat value in a coal may be estimated. This has been tried by using the percentage of ash and volatile matter or ash and fixed carbon, but since these constituents are so variable in their composition, depending upon their sources, it is impossible to arrive at a reliable formula. For that reason a calorimetric determination must be made. The analyses and fusing temperature determinations in Tables I. and II. were made on bituminous and semi-bituminous coals.

Table II.—*Fusing Temperature of the Ash in Coal arranged according to the Iron Content of the Ash.*

No.	Iron oxide	Sulphur in coal	Ash in coal	Fusing temperature	No.	Iron oxide	Sulphur in coal	Ash in coal	Fusing temperature
1	4·81	·51	5·15	2,700	20	22·57	2·00	9·03	2,336
2	6·28	1·01	9·15	2,600	21	23·17	1·16	9·52	2,535
3	7·29	·90	6·41	2,600	22	23·30	2·40	8·10	2,156
4	7·88	·74	5·57	2,600	23	24·40	2·23	10·90	2,190
5	7·94	1·52	15·61	2,750	24	26·50	2·13	6·86	2,192
6	11·28	1·04	8·53	2,745	25	27·22	3·13	13·54	2,138
7	13·84	1·80	13·51	2,300	26	28·39	1·96	6·65	2,084
8	14·14	1·46	7·88	2,615	27	28·81	2·32	7·55	2,318
9	15·15	1·07	6·38	2,560	28	30·67	2·17	7·90	2,246
10	15·21	1·42	7·98	2,400	29	33·27	2·86	9·33	2,520
11	15·38	1·57	—	2,156	30	35·13	2·13	6·25	2,300
12	16·00	1·63	9·90	2,309	31	36·12	3·04	8·40	2,264
13	17·43	—	7·98	2,516	32	36·17	2·60	7·50	2,500
14	17·95	2·11	11·04	2,309	33	38·75	3·97	10·60	2,180
15	19·19	1·79	7·90	2,138	34	39·51	2·97	8·22	2,210
16	19·54	2·41	11·33	2,380	35	39·88	2·41	8·96	2,372
17	22·26	2·06	9·70	2,400	36	40·93	2·68	9·08	2,415
18	22·26	1·90	7·23	2,372	37	44·00	4·12	—	2,246
19	22·38	2·56	—	2,210	38	44·39	3·51	9·34	2,318

No.	Per cent.	Deg. Fah.
9	15·15 iron oxide	2,560 fusing temperature.
10	15·21 ,,	2,400 ,, ,,
11	15·38 ,,	2,156 ,, ,,
21	23·17 ,,	2,535 ,, ,,
22	23·30 ,,	2,156 ,, ,,
31	36·12 ,,	2,264 ,, ,,
32	36·17 ,,	2,500 ,, ,,

No.	Deg. Fah.	Per cent.
11	2,196 fusing temperature	15·38 iron oxide.
33	2,180 ,, ,,	38·75 ,,
16	2,380 ,, ,,	19·54 ,,
35	2,372 ,, ,,	39·88 ,,
13	2,516 ,, ,,	17·43 ,,
32	2,500 ,, ,,	36·17 ,,
15	2,156 ,, ,,	19·19 ,,
25	2,138 ,, ,,	27·22 ,,

It may be noted from these tables that some coals have ash of like iron content and variable fusion temperature; then again, others have ash of like fusion temperature and variable iron content. It would appear from these analyses that there is no relation between the percentage of the various constituents of the ash and the fusing temperature. Therefore a chemical analysis is of no value to arrive at a conclusion regarding the clinkering quality of a coal. It may be noted that although coals having an ash with a very low iron content seem to give the highest fusing ash, no definite fusing temperature fits a definite percentage, and when the iron content goes beyond 10 per cent. the fusion temperature cannot be judged at all. That the sulphur content of the coal has no bearing whatsoever upon the fusibility of the ash is also apparent. Since the sulphur occurs in coal combined either with iron, lime, or the hydrocarbons, there naturally exist innumerable combinations, and for this reason the sulphur content cannot be used as an index to clinkering. Only in those cases in which the sulphur is in combination with the iron in the form of pyrites would it be possible to judge the clinkering property, if the iron content in the ash had any bearing upon the fusion temperature.

* Paper read before the American Society of Chemical Industry.

The fusion temperature determination of the ash in coal will in the future displace the sulphur determination in such coals used for steaming purposes, and will readily show the fallacy of buying and selling coal on an analysis basis where specifications are used containing sulphur tables penalising beyond a certain guaranteed amount of sulphur. It has been quite a common practice to place 1·50 per cent. sulphur as a limit and penalising as much as 2d. per ton for every 0·25 per cent. above 1·50 per cent. The injustice of this practice is very evident, as it often happens that coals with a high sulphur content are extremely high in heat value and do not clinker readily at all. Since the sulphur has no appreciable effect upon the metallic parts of the furnace it need therefore not be considered in the selection of a coal for steaming purposes. To arrive at the value of a coal for steaming purposes it is therefore just as essential to make the fusion test of the ash as it is to make the calorimetric determination. If these determinations are made, an explanation is readily had why two coals of apparently like proximate analyses will give entirely different evaporation when fired under like conditions.

RAIL STEELS AND RAIL CORRUGATION.

At a meeting of the Institution of Civil Engineers held in London on Tuesday last two papers were presented: (1) "Rail Steels for Electric Railways," by William Willox, M.A., M.Inst.C.E.; and (2) "Rail Corrugation and Its Causes," by Stephen Prescott White D'Alte Sellon, M.Inst.C.E. The author of the first paper said that the reduction of the life of rails in tunnels from an average of five years to an average of less than three years, and in certain places to less than one year, on the electrified portion of the Metropolitan Railway, induced him to make tests of various kinds of steel rails in the curve between Farringdon Street and Aldersgate. The paper described the results of these tests, and also the results of tests for wear of various steels, including manganese steel, in points and crossings. The traffic over the curve mentioned was, he remarked, exceedingly heavy, and in the morning and evening there were 42 booked trains per hour on one line. Chemical analyses, tensile tests, tup tests, and impression tests had been made of all the rails used, and sections of the rails had been etched. Taking into consideration these tests, the fact that railways must keep the cost of their permanent way within reasonable limits, and that the cost of re-railing was very high, where only 2½ to 3 hours were available for this work, namely, between midnight and early morning, the author had come to the conclusion that open-hearth basic Bessemer rails, manufactured by the late Mr. C. P. Sandberg's process, and under careful supervision, had proved the most economical. The number of broken rails for the last six years had been very small; the wear after five years of one of these broken rails in the tunnel being only ¼lb. per yard. The result of the use of manganese-steel rails in the curve referred to was also given, and should prove interesting, as rolled manganese-steel rails, so far as the author was aware, had been little used in England, even in crossings.

In the second paper the author stated that the corrugation of rails had become general and serious upon railways and tramways since the introduction of electric traction, and seriously exercised the owners of such undertakings. Investigations organised by many associations in various parts of the world had not discovered a solution of the trouble, or propounded any theory of the causes which had found general acceptance; nor had they put forward any remedy. Large expenditure was being incurred by many tramway undertakings in grinding out corrugations, thereby shortening the life of the rails abnormally. It was estimated by the general manager of the City of Glasgow Tramways that his undertaking spent not less than £10,000 per annum in this grinding operation.

The author was of opinion that the rail steel now used for rails was not hard enough or tough enough for its work. Possibly modern methods of steel and rail making were at fault in this direction. The use of wheels of small diameter was evidently severe on the rails, but the conditions of tramway working made alteration impracticable. It therefore became necessary to find a material which would not yield to the wheel actions, which were the immediate cause of corrugation. The author believed that hard rails—*i.e.*, with a high proportion of carbon—were essential, and gave some evidence from his own and others' experience that such high carbon rails resisted the corrugating actions of the wheels, as well as ordinary wear. The British Standard specifications were established before corrugation was realised as a serious possibility, and the range of carbon content permitted, besides being rather wide, only approached the hard side for Bessemer steel, whilst it was on the soft side for open hearth steel.

The general character of corrugation was described, stress being laid upon the facts that the "crests" had the appearance of planished or cold rolled steel, and were relatively hard and refractory to acid; and that the "hollows" were dull, showed some lateral detrusion and pitting, and were only slightly harder than the body of the steel. The author arrived at the conclusion that the "crests" were cold rolled, and the "hollows" were surface which had been crushed, due to the vertical loads imposed by the wheels oscillating about the elastic compressive limit of the steel. How the oscillatory character of the load was brought about was not considered, but it was pointed out that at ordinary speeds the usual pitch of the corrugations on tramway rails corresponded with a frequency of the order of 100 per second. The difference between this periodicity and that causing the corrugation of macadam roads by motor-vehicles was referred to. The possibility of the rails receiving initial corrugations in the processes of rolling and cooling was briefly discussed, but it was pointed out that such initial corrugation, if it ever existed, was uncommon. Differences of surface hardness or internal stresses received during manufacture were suggested as possibilities.

Leaving these suggestions, the fact remained that corrugation was due to the failure of the rail table under the stresses imposed upon it. The surface was alternately cold rolled and disintegrated. The measurements of static pressure made by Mr. Worby Beaumont, and set out in the paper he presented to the British Association in 1911, proved that pressures of such magnitude as to produce destructive effects occurred, but that it was probable that the compressive elastic limit of rail steel was not generally exceeded. The evidence, therefore, seemed to show that a comparatively small increase in the compressive strength of the steel would prevent the particular kind of wear under consideration.

The author suggested that the essential points to be specified were mechanical properties corresponding with the working stresses imposed upon the rails, and first compressive strength. The British Standard specification prescribed an ultimate tensile strength of 40 tons per square inch, the compressive strength was probably about the same as the tensile; the actual wear of tramway rails suggested that it was somewhat in excess of 40 tons per square inch. Probably steel with an ultimate tensile strength of 50 to 60 tons per square inch would be hard enough to resist the destructive stresses, but it was essential that it should not have a high degree of ductility. The minimum pressure needed to produce surface crushing and flowing should be determined. It was suggested that a Brinell test might give all the information needed. The test might have to be modified, but rails laid on a continuous concrete substructure had a large margin of safety against breakage from vertical shocks, and a less severe tup test should suffice. The whole specification of the rail in respect to its mechanical qualities should bear a direct relation to the stresses which it would be called upon to resist.

Junior Institution of Engineers: Sheffield Branch.—At a meeting of the Sheffield and district members of this Institution held at Sheffield on Saturday last, it was decided to constitute a local section with Sheffield for its centre, and the following committee was elected *pro tem.*: Messrs. J. A. Little, Thomas Firth, F. W. Mellowes, J. R. Williams, and R. J. Stanley.

West of Scotland Iron and Steel Institute.—At a meeting of this Institute held in Glasgow on Friday last, a paper, illustrated by lantern slides, was read by Mr. H. V. Kramer on "The Application of Electric Magnets in Iron and Steel Works." A discussion followed. The President intimated that at the March meeting a paper would be read by Messrs. Cecil H. Desch and Samuel Whyte on "The Influence of Manganese on the Corrosion of Steel."

DESIGN AND CONSTRUCTION OF HYDRAULIC TURBINES.*

H. BIRCHARD TAYLOR, M.AM.SOC.M.E.

(Concluded from page 183.)

Speed Regulation.—In addition to considerations of efficiency, deterioration and mechanical arrangements of turbines, the question of speed regulation is of great importance where turbines are employed for driving alternators. Speed regulation is obtained by means of a governor driven from the turbine shaft, consisting primarily of a governor head containing flyballs controlled by springs and connected through a pilot valve to the main governor valve. At normal speed the flyballs hold the governor valve in its mid-position, but for any change in speed the flyballs move the valve, admitting pressure through a suitable number of relay valves to an operating cylinder so that the turbine gates are adjusted to suit the new load and to obtain the normal speed. Some of the chief considerations in connection with speed regulation are:—

(1) Sensitiveness of the governor head involving quick response to sudden changes of speed and also response to slight changes of speed.

(2) Steadiness or stability of action. This quality is an important one and involves freedom from unnecessary gate movements or movements occasioned by conditions other than changes of load on the unit. It is not only necessary for a governor to respond to changes of load, but it is equally important that it shall not act when there is no change of load. The continual motion and vibration of the turbine gate mechanism produced by unstable governors is a source of wear and rapid deterioration of the gate mechanism which in turn accentuates the lack of stability and is very objectionable. In older types of governors this tendency was usually overcome by the use of a dashpot to damp such motions, but the use of a dashpot for this purpose renders the governor sluggish and impairs its action.

(3) Power of governor. For large units, a large amount of power is required to actuate the turbine gates. This power may be obtained from a delicate governor head by the use af a series of relay valves controlled primarily by a small pilot valve attached to the governor head. In order to obtain sufficient fluid to move the operating piston, the main valve on the operating cylinder must be large and heavy; so that with a large unit either a considerable number of intermediate valves between the pilot valve and the main valve must be used, or else the governor head itself must be given a considerable amount of power. The same result could perhaps be accomplished by the use of high pressures in the governor system, but the use of such pressures has proved very unsatisfactory in practice and has been abandoned in favour of moderate pressures. Since time is required for sufficient fluid to flow through each valve to move the next valve in series, increase of power by such means is limited by the speed of action required. The best solution seems to be in the use of flyballs having a weight and power corresponding in order of magnitude to the turbine which they must control. Such increase in power in the flyballs involves no sacrifice in sensitiveness, since the governor head is mechanically connected to the turbine shaft and is forced to respond immediately to any change in speed of the unit. The sensitiveness will, in fact, be increased by the use of heavy flyballs, since the retarding effect of friction can be made relatively less.

(4) Reliability in operation. It is recognised by engineers of experience that delicate and complicated mechanisms should be avoided, and all machinery made to stand severe service and to be as nearly fool-proof as possible. For this reason governors in important stations should be of as simple and rugged a design as possible. The effect on a large and heavy governor of accidental conditions, such as the presence of grit in the governor fluid or sticking of the governor parts, will be slight as compared with the effects on a delicate piece of apparatus.

(5) The pressure system used was formerly divided into a separate pumping equipment for each unit in a station. This has been abandoned in favour of a single pumping system supplying the entire station. This change has greatly reduced the cost of attendance and has improved the continuity of service. The open system of governing is now being used in which oil or water for the governors is pumped from an open tank and no pressures less than atmospheric are used at any point in the system. This change avoids troubles caused by air collecting in the pipes or pumps or the breakdown of oil under high vacuum.

(6) Hand control. Another recent improvement is in the nature of the hand control used for the operation of the turbine gates. Originally the hand control of a turbine was accomplished by mechanical means through trains of gears. The mechanical efficiency of such a mechanism is so low that the time required to close the gates of a large turbine by such means is prohibitive. The mechanical hand gear was gradually replaced by a hand wheel incorporated in the design of the governor, controlling the turbine gates by oil pressure through the main valve of the governor. This arrangement, however, although it has been recently used by a number of the standard governor builders, is subject to the objection that should the governor valves be dismantled for repairs the turbine must be shut down, and it is poor engineering to dispense with the services of the turbine for the sake of a governor valve. The best method of hand control now adopted for large units seems to be in a separate device, entirely independent of the governor and placed at a convenient point, and so designed as to admit oil from the central pumping system directly to the turbine operating engine. A restoring mechanism connection from the turbine gates maintains these gates in a position corresponding to the position of the hand wheel. By this means it is possible to move by hand the gates of the turbine through their entire range in approximately ten seconds of time. Except for units of very large size, a small hand-operated plunger pump may be supplied in connection with the operating stand, by means of which it is possible to create pressure for the movement of the gates in the event that the central pumping system is temporarily out of service.

(7) The mechanism of the modern governor itself has been reduced to a few comparatively simple operations. Certain compensating devices are required to restore the governor valves after the required gate movement has been produced and also to restore the speed of the turbine to the required value after the water column in the penstock, turbine casing, and draught tube has had time to be accelerated or retarded to its new value. The governor should also have adjustments, so that the change in speed from full load to no-load conditions may be fixed to suit the parallel operation of alternators, also to adjust the time of action of the governor to suit the length of and velocities in the water passages, and an attachment for changing the normal speed of the turbine. Modern governors are also fitted with motors by means of which the speed of the turbine can be adjusted from a distant point, such as the switchboard, this device being used in synchronising the unit.

The above points cover all the features which can be controlled in the design of the governor itself. The speed regulation of a unit, however, depends on several other factors which are invariably of greater importance than the action of the governor itself; these are the length of and velocities in the penstock and draught tube, as well as the length of the water column in the turbine casing itself; also the "flywheel effect" of the rotating masses of the generator and turbine.

A perfect governor will be unable to produce a speed regulation better than that permitted by the factors just mentioned. These factors are controlled by the design of the power development as a whole, so that the actual speed regulation obtained is only affected to a limited extent by the construction of the governor itself. Properly, all of these factors should be considered together.

In a majority of the large installations recently undertaken, turbine governors have been designed and constructed by the builders of the turbines, thus producing a governor suited to the exact conditions of each turbine and avoiding the division of responsibility which has so often proved to be a source of annoyance. The better appreciation of the factors entering into governor problems has resulted in greatly improved speed regulation which, when taken in connection with valuable improvements in the mechanical design of the governor, has removed this important auxiliary from the class of necessary evils and placed it in that of reliable machinery.

* Abstract of paper read before the Canadian Society of Civil Engineers, January 15th, 1914.

OIL FUELS AND THEIR APPLICATION TO THE GENERATION OF POWER.*

BY PROF. THOMAS GRAY, D.SC., AND PROF. A. L. MELLANBY, D.SC.

(*Continued from page 174.*)

Creosote Oil and Tar Oils.—The creosote oil produced in Great Britain is practically entirely used for preserving timber; a relatively insignificant amount of the oil is burned in metallurgical furnaces and used for lighting. In Germany, on the other hand, these oils have been extensively used for the generation of power; and as fuels for Diesel engines they are much superior to the crude tars, on account of the greater

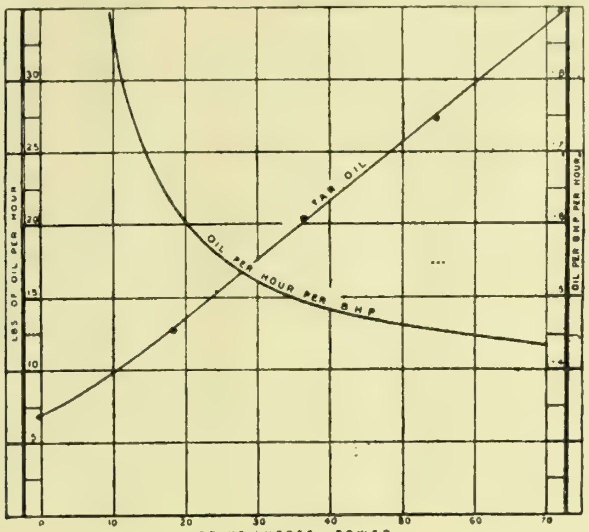


FIG. 1.

uniformity of their composition and relative freedom from ash and water. The most complete information regarding the properties of these oils is due to Constam and Schläpfer (*loc. cit.*, p. 1,621), who give the constants of 29 samples, ranging in specific gravity from 0·971, in the case of "first runnings," to 1·110 in the case of an anthracene oil; the mean specific gravity of all the samples was 1·055. The oils contained less than 0·05 per cent. of ash in all but two cases, and more than half the number were entirely free from ash, or contained merely traces; the proportion of water present exceeded 0·5 per cent. only in 6 of the 29 samples.

The limits of variation of the composition of the dry, ash-free oils were: Carbon from 87·0 to 91·4, hydrogen from 6·0 to 7·9, and sulphur from 0·3 to 1·0 per cent., and the average values were: Carbon 88·9, hydrogen 6·9, and sulphur 0·6 per cent. The higher calorific value of the dry, ash-free oils ranged from 16,625 to 17,111, average, 16,837, and the lower calorific value of the original oils from 15,921 to 16,425, with a mean value of 16,094 B.Th.U's. per pound. Lunge and Köhler give a few of the constants of 10 samples of tar oil; the average gross and net calorific values of the commercial oils were, respectively, 16,740 and 16,072 B.Th.U's. per pound. Blastfurnace creosote oil is slightly lighter than water, and is entirely liquid at ordinary temperatures. It contains a larger proportion of hydrogen, and has a higher calorific value than the creosote oil derived from the high temperature coal tar.

The difficulties encountered in the earlier trials with tar oils in the Diesel engine, caused by the high temperature necessary for the ignition of these oils, have been overcome in two ways†: (1) The compression is increased to raise the temperature of the air to the level at which the oil ignites with certainty. (2) An auxiliary oil, which ignites easily, is employed to ignite the tar oil.

The first method may be employed in the case of any engine of normal design if the machine is warm and running on a high load, but when starting, or running on light load, a petroleum oil is required; arrangements for the supply of both classes of oil must, therefore, be provided. Nägel states, however, that the Maschinen-Fabrik, Augsburg, has recently succeeded in securing the ignition of tar oils under normal compression by means of a slight alteration of the valve gear, which reduces to a minimum the amount of cold air entering with the oil; the cooling effect of an excessive quantity of air from the blast is thus prevented, and the engine may be run on tar oils alone, starting cold, under all conditions of load.

The second method is the one most generally employed. With the help of a second pump the auxiliary fuel—usually gas oil or petroleum—is forced into a circular channel which surrounds the conical seat of the main fuel valve. When the valve opens, the small quantity of gas oil, amounting only to a few parts per hundred of the tar oil, enters the cylinder in advance of the main oil supply, and immediately takes fire, thus ensuring the ignition and quiet combustion of the tar oil which follows.

Reports of trials made upon Diesel engines using tar oil are given by Nägel,‡ and are represented graphically in Figs. 1 and 2. Fig. 1, which refers to a trial of a 70 h.p. engine, constructed by the M.A.N. Company at Augsburg, illustrates how the consumption varies with the load in an engine working upon a tar oil alone. The curve of oil used per hour represents the mean of the measured quantities, but the curve of oil per hour per horse-power has been calculated to a standard oil of 18,000 B.Th.U's. calorific value. In Fig. 2 are shown the results of tests of a 60 h.p. tar oil engine, constructed by the Deutz Gas Engine Company, in which gas oil was used for the ignition of the tar oil. The curve of oil per hour per horse-power has also been calculated in this case to a standard of 18,000 B.Th.U's.

Our experiments with creosote oil, produced locally, gave results which fully confirm continental experience. These trials were made with Bedlay coke-oven oil upon a Diesel engine at the Royal Technical College, Glasgow. This engine was designed to use petroleum, and no alterations were made for these trials beyond increasing the compression and making the fuel valve open a little earlier. The oil as delivered contained a large amount of naphthalene, which was removed by cooling it to 55° Fah., and subsequently filtering. In the filtered condition the specific gravity at 60° Fah. was 1·046, and the lower calorific value 15,997 B.Th.U's. per pound. An attempt was made to start the engine with this oil, but so many violent explosions occurred during the process that it was given up, and the usual procedure adopted was to start up, load the engine with gas oil, and then switch over to the reservoir containing the coke-oven oil. No difficulty was experienced in running the engine upon full or three-quarter

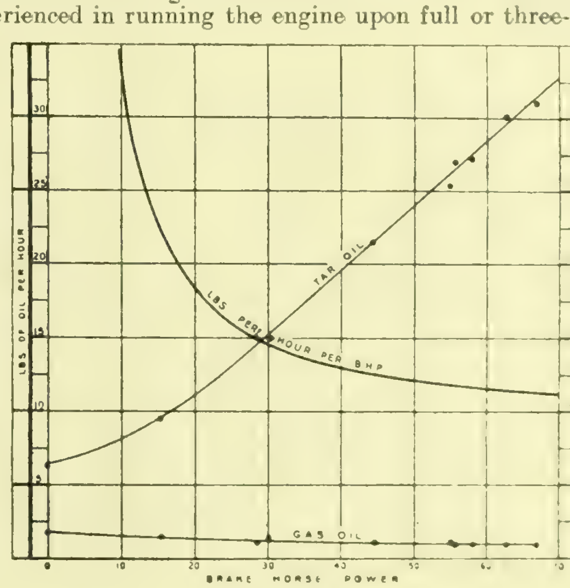


FIG. 2.

load, but at the lighter loads trouble commenced, and the explosions became so serious that the low-load trials were abandoned.

The results obtained with three different loads are given in Table I. It will be noticed that the total oil consumption at 24 b.h.p. was greater than at 29·5 b.h.p.; this was obviously due to the imperfect combustion at the lower load, and indicated that a large amount of unburnt fuel was passing away with the exhaust. The tachograph records in Fig. 3

*Abstract of paper read before the Institution of Engineers and Shipbuilders in Scotland, January 20th, 1914.

† Nägel: Die neuere Entwickelung der ortfesten Oelmaschine, Zeit Ver deutsch Ingen., 1911, 1340.

‡ *Loc. cit.*, pp. 1313 and 1341

illustrate the manner in which the engine ran under the different conditions. Record (*a*) is for trial 1, and shows that the engine speed was quite constant throughout the trial; (*b*) is for trial 2, and shows a slight occasional variation, but, on the whole, fairly constant running; (*c*) is for trial 3, and gives evidence of the variable speed of the engine; (*d*) is for a trial when the load was reduced to give about 20 b.h.p., and shows conclusively how badly the engine ran at what was a little over half load. Some idea of the nature of the explosions referred to can be obtained from Fig. 4, where (*a*) shows the rotary diagram when the engine was running steadily as in trial 1, and (*b*) shows a similar rotary card when running under the conditions of record (*d*), Fig. 3. The fact that these explosions took place after the crank had passed the dead centre while the piston was moving with considerable velocity on the expansion stroke, gives an indication of their violence. The oil consumption during this trial was very high, as indicated by the low speed and the condition that the lower the speed the more oil is injected into the cylinder per stroke. No results from this test are given, as the engine was not run for a sufficiently long time to obtain any measurements.

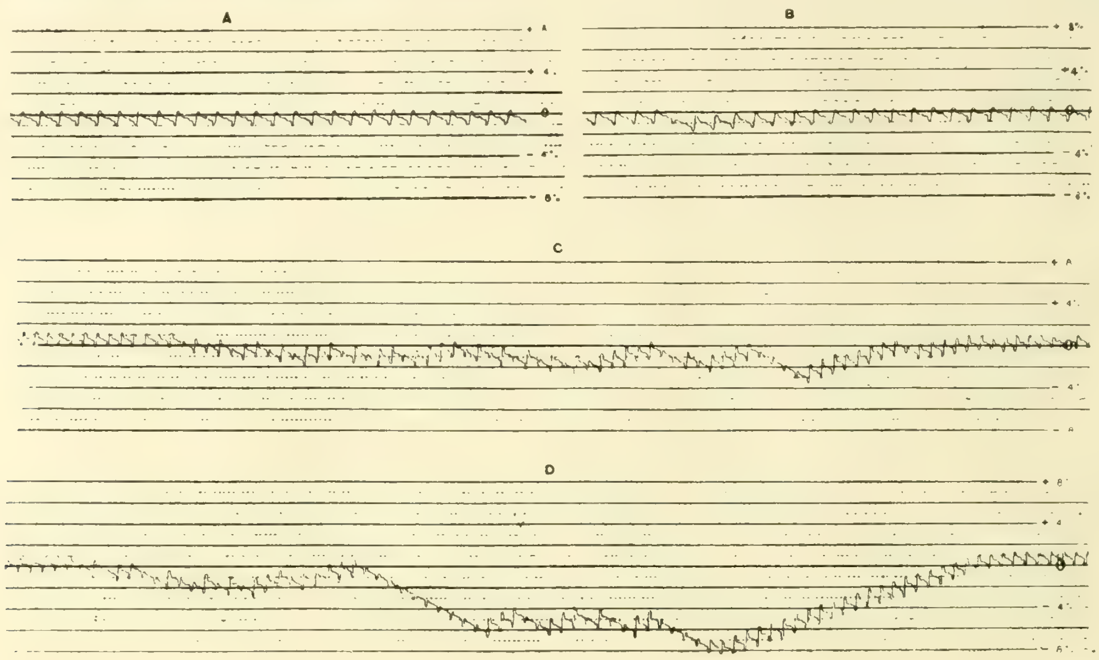


FIG. 3.

TABLE I.—*Diesel Engine Trials with Bedlay Coke-Oven Oil.*

Diameter of Cylinder 12in.; Stroke 18¼in.

Number of trial	1	2	3
Date of trial	5/6/13	5/6/13	17/6/13
Average revolutions per minute	202·2	202·6	202·6
Mean effective pressure (lbs. per sq. in.)	99·3	86·5	—
Indicated horse-power	52·0	45·0	—
Brake horse-power	35·5	29·5	24·1
Blast pressure (lbs. per sq. in.)	706	675	635
Exhaust temperature (deg. Fah.)	714	672	—
Oil used per hour (lbs.)	19·10	17·45	17·82
Oil used per hour per b.h.p. (lbs.)	0·538	0·592	0·74
Oil used per hour per b.h.p. (lbs.) reduced to a calorific value of 18,000 B.Th.U.'s.	0·478	0·526	0·658

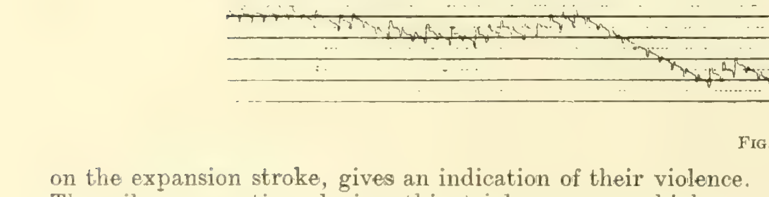


FIG. 4.

It seems clear from these experiments that an ordinary Diesel engine can be run upon coke-oven oil without making any serious changes in the fuel-valve arrangements, provided it is always working in the neighbourhood of full load. For light loads, however, a supply of petroleum should be available. The trial results in Table I. indicate that at the higher loads the efficiency was quite up to expectations. In the last line of the table the oil consumption has been reduced to a standard oil of 18,000 B.Th.U's. calorific value for purposes of comparison with the two engines using tar oil previously referred to.

Benzol.—The commercial varieties of benzol are mixtures of benzene with the two higher members of the benzene series, viz., toluene and xylene; they are known by the trade names "90 per cent. benzol" and "50 per cent. benzol," which indicate that 90 and 50 per cent. by volume respectively distil over below 100° C. The first-named consists principally of benzene, whereas the 50 per cent. benzol, being the higher boiling fraction from the distillation of the crude benzol, contains a large proportion of toluene and xylene.

A sample of 90 per cent. benzol may be expected to have the following constants: Specific gravity 0·88 to 0·885; freezing point about 20° Fah.; carbon about 92 per cent.; hydrogen about 8 per cent.; higher calorific value about 18,050 B.Th.U's.; lower calorific value about 17,270 B.Th.U's. The freezing point of 50 per cent. benzol is considerably lower than that of the 90 per cent. benzol, and its calorific value is slightly higher; but, on the other hand, its volatility is less, and greater difficulty is consequently experienced in vaporising it with air.

The chief applications of benzol are: (*a*) As a raw material for the manufacture of pure chemicals, including dyes, drugs, explosives, and photographic chemicals; (*b*) as a solvent, particularly in the india-rubber, paint and varnish industries; (*c*) for denaturing alcohol; and (*d*) as a fuel. Up till a few years ago the bulk of the benzol production was absorbed in the manufacture of organic chemicals and dyestuffs, but now, even in Germany, the home of these industries, the proportion sold as motor spirit exceeds that used in colour works.

Benzol is readily vaporised by air, and may be substituted for petrol as a fuel for motor-vehicles, without any change other than a slight adjustment of the carburetter. The calorific value of benzol per unit of weight is considerably lower than that of petrol, which, in the case of a spirit having a gravity of 0·72, may be assumed to be approximately 20,200 B.Th.U's. (gross) or 18,750 B.Th.U's. (net). But if the unit of volume, which is the basis of sales, is chosen for comparison, the advantage lies with benzol, as is evident from the following statement:—

	Specific Gravity.	Net Calorific Values of Benzol and Petrol. British Thermal Units.	
		Per lb.	Per gallon.
Benzol	0·883	17,270	152,500
Petrol	0·72	18,750	135,000

Assuming the same efficiency with the two fuels, these figures indicate an increased duty in the case of benzol of approximately 13 per cent., and this figure accords fairly well with the results of tests by various experimenters.

In a summary of the experiences of over 50 users of benzol as a fuel for motor-vehicles, which appears as an appendix to the second report of the Petrol Committee of the Royal Automobile Club, the statement is made that benzol appears to give on an average "15 per cent. more mileage than petrol, and greater pulling power." The chief disadvantages alluded to are: (1) a difficulty in starting in cold weather; (2) a more objectionable exhaust; and (3) sooting of the valves; while opinions vary as to carbonisation in the cylinders, which, however, does not appear to be greater than with petrol.

The possibility of working with benzol at higher compressions and with a consequent greater efficiency is a noteworthy advantage; benzol-air mixtures may be compressed to from 10 to 12 atmospheres without fear of explosions, whereas pre-ignitions take place when petrol-air mixtures are compressed above 5 atmospheres.

TABLE II.—*Diesel Engine Trials with Pumpherston Gas Oil. Diameter of Cylinder 12in., Stroke 18¼in.*

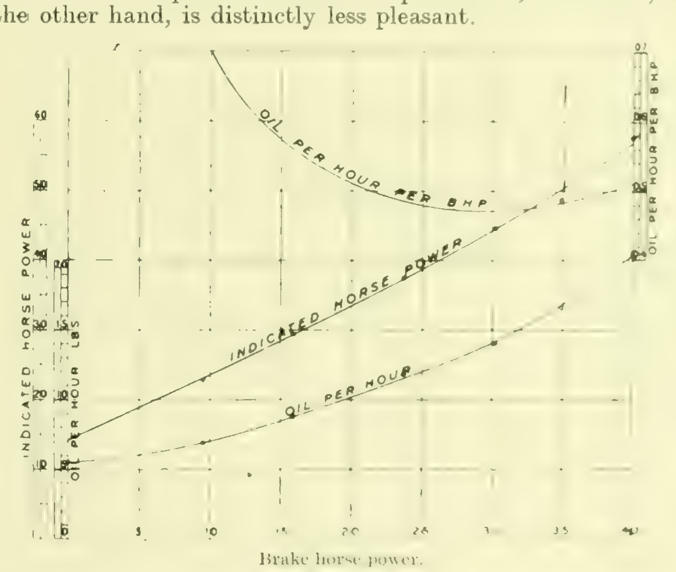
		1	2	3	4	5	6	7
Number of Trial		1	2	3	4	5	6	7
Date of Trial		10/12/12	10/12/12	10/12/12	12/12/12	12/12/12	12/12/12	17 12 12
Average revolutions per minute		206·5	205·8	204·9	204·0	203·1	202·0	201·3
Mean effective pressure (lbs. per sq. in.)		—	42·4	55·1	70·5	84·1	92·4	109·7
Indicated horse-power		—	22·8	29·4	37·5	44·6	48·7	57·7
Brake horse-power		0	9·5	15·9	23·7	30·2	34·9	40·0
Blast pressure (lbs. per sq. in.)		530	570	611	664	691	735	764
Exhaust temperature (deg. Fah.)		226	315	394	502	595	684	—
Jacket-water inlet temperature (deg. Fah.)		64·0	65·2	65·0	64·8	63·4	62·2	—
Jacket-water outlet temperature (deg. Fah.)		103·2	117·4	123·8	—	135·9	139·6	—
Jacket-water used per hour (lbs.)		510	500	637	—	870	972	—
Oil used per hour (lbs.)		5·52	6·88	8·80	11·82	14·09	16·65	20·6
Oil used per hour per b.h.p. (lbs.)		—	0·723	0·554	0·499	0·467	0·477	0·515
Composition of exhaust gases per cent. by volume.	Carbon dioxide	1·62	2·71	3·66	5·19	6·14	8·16	9·70
	Carbon monoxide	0·13	0·08	0·04	0·04	nil.	nil.	0·04
	Oxygen	18·73	17·32	16·09	14·00	12·40	10·06	7·92
	Nitrogen	79·52	79·89	79·21	80·77	81·19	81·78	82·34

The tendency to freeze at comparatively moderate temperatures is a decided drawback to the use of 90 per cent. benzol. To obviate this, mixtures of benzol and alcohol in equal volumes (motoline), of benzol, petrol, and alcohol, and of 90 per cent. benzol with the higher hydrocarbons in the proportions in which they occur in coal tar (ergin) have been employed. The last-named proposal seems to offer the most practical solution of the difficulty, except in abnormally cold localities, where mixtures of benzol and petrol would prove more suitable.

The value of benzol as a fuel for motor-vehicles was first appreciated in France, where its employment for this purpose has extended rapidly during the last five years. It has been estimated that the consumption in France during 1910 was approximately 50,000 tons (12½ million gallons), the greater part of which was imported from England, Germany, and Belgium. The German Benzol Association reports the probable consumption in motors of the benzol produced in Germany during 1913 as 80,000 tons, and for 1914 as 95,000 tons. In Great Britain the use of benzol as a fuel has hitherto been largely confined to the officials of coke-oven works and tar distilleries, and to motorists in the neighbourhood of these works. The recent advances in the price of petrol have, however, led many users of motors to experiment with benzol, and reports as to increased mileage and greater pulling power have appeared regularly in the various motor journals. The use of benzol at the present time is only restricted by the comparatively limited output, and the lack of facilities for distributing it to the consumers.

Shale Oil.—Crude shale oil is dark brown in colour, and has a specific gravity ranging from 0·86 to 0·89. It is solid at ordinary atmospheric temperatures, and melts somewhere in the neighbourhood of 90° Fah. The whole of the shale oil, at present produced in Scotland, is distilled and refined to yield spirit, naphtha, burning oils, lubricating oils, and paraffin wax. In the crude form it has not hitherto been used as a fuel, but the possibility of producing crude oil for this purpose appears to be well worth serious consideration if the present high prices of fuel oils are maintained. The presence of paraffin wax, which causes it to solidify, and would necessitate the provision of steam coils to keep the material in the molten condition, is a drawback to the use of the crude oil in its present form. The solid paraffins are, however, readily decomposed by heat with formation of more volatile liquid hydrocarbons, and experience with petroleums indicates the probability that the crude oil might be converted, by a simple "cracking" treatment, into motor spirit on the one hand and a heavy crude fuel oil on the other. This proposal does not affect the present output of crude oil, from which the market requirements for refined products would be supplied as before. Its practical realisation would involve the erection of additional retorts and condensing plant; but, in the simplified treatment for the purpose of producing a crude fuel oil, the costly appliances necessary for the separation and refining of the paraffin wax, viz., the refrigerating, filtering, pressing, and sweating plant would be dispensed with, and the cost of converting the crude oil into a saleable product would be greatly reduced. The financial possibilities of such a scheme will doubtless receive the careful consideration of the existing shale oil companies.

The shale spirit and naphthas are used as motor spirit, for lighting in special flare lamps or miners' safety lamps, and for solvent purposes. A carefully-fractionated Scotch motor spirit of specific gravity about 0·718 has a distillation range and a calorific value practically identical with those of a similar motor spirit derived from petroleum; its odour, on the other hand, is distinctly less pleasant.



Brake horse power.
FIG. 5.

The burning oils are used almost exclusively for illuminating purposes. Although we have tried on several occasions to use them with an ordinary Otto cycle oil engine with a hot vaporiser, the results have not been entirely successful. When the Scotch oil was used under conditions of jacket-water temperature, which proved perfectly satisfactory with Russian and American burning oils, the explosions were violent and irregular, and the engine worked in a very erratic manner. These difficulties vanished when the flow of jacket water was increased considerably, and the engine ran smoothly with an oil consumption practically identical with that observed in the

trials using the petroleum oils. We understand that similar difficulties have been experienced by other observers.

Apart from the motor spirit already referred to, the gas oil or intermediate oil is the only product of the distillation of shale which has been extensively used as a fuel. Gas oil is the portion of the distillate which is too viscous for use as an illuminant, and too fluid to be used for lubricating purposes—hence the name intermediate oil. Up till a few years ago, the only large outlet for this oil was in the manufacture of oil gas and carburetted water-gas. It has since that time been adopted by the British Admiralty as a fuel, and is now in large demand locally for the generation of heat and power. The specific gravity of gas oil varies somewhat, owing to the inclusion of the lighter grade of lubricating oil when the demand for the latter is small. The usual grade has a specific gravity in the neighbourhood of 0·86, and a net calorific value of about 18,200 B.Th.U's. per pound. It is a highly-refined oil, entirely free from water and ash, and is an excellent fuel for Diesel engines.

To give some idea of the results to be expected from the use of shale oil in a Diesel engine, a series of trials was made with Pumpherston gas oil upon the experimental engine in the Royal Technical College, Glasgow. The specific gravity of this oil in the filtered condition was 0·864 at 60° Fah., and the lower calorific value 18,214 B.Th.U's. per pound. This engine was supplied by Messrs. The Mirrlees Watson Company, Ltd., in 1906, and has since then been in continual use for ordinary laboratory purposes. Its dimensions are: Diameter of cylinder, 12in.; stroke, 18¼in.; and normal revolutions per minute about 200. The engine is loaded by means of a rope-brake applied to a water-cooled rim, 9ft. diam., bolted to the

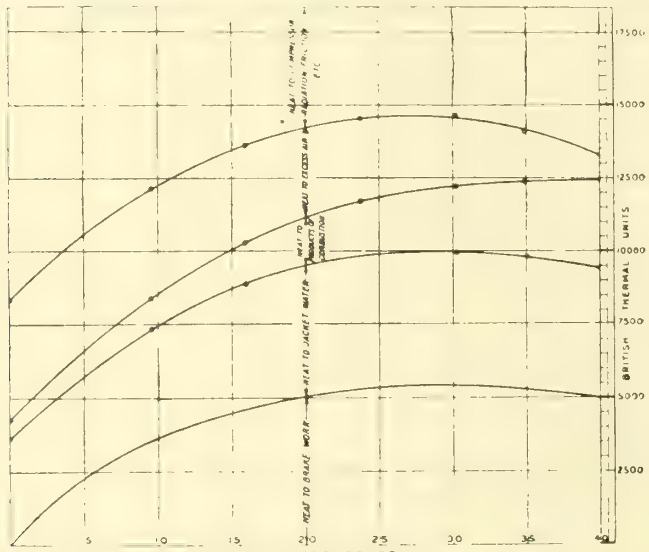


FIG. 6.

flywheel. A 2-stage air compressor for supplying the blast and starting air is driven by a crank at the end of the engine crank shaft. No attempt was made to measure the horse-power absorbed by the compressor during these trials. In addition to the ordinary cards, several rotary indicator diagrams, similar to those illustrated in Fig. 4, were taken. This was done by removing the spring from an indicator barrel and then driving the barrel continuously by a belt from a countershaft connected to the cam shaft. Diagrams of this type have some advantages over the ordinary indicator card, since they permit the pressure changes during compression and admission to be more easily studied. Great care was taken to ensure accuracy in the measurement of the oil used by the engine. As it was desired to investigate very accurately the various ways in which the heat stored up in the fuel was disposed of, great importance was attached to accurate sampling and analysis of the exhaust gases. The analyses of the samples were conducted over mercury in a Haldane gas analysis apparatus. All the other necessary observations were taken at five-minutes intervals during the test. Preliminary tests were made to determine the best blast pressures for the various loads, and these were ultimately adopted.

In Table II. are given the main results of a series of trials varying from no load to full load. Curves showing the oil used per hour and per hour per brake horse-power are given in Fig. 5 to a base of brake horse-power, and another set of curves giving the amount of heat used as work and that dissipated in exhaust gas, jacket-water, &c., for each pound of oil at the different loads are given in Fig. 6. The results appear very favourable for an engine of this size, and show that, even in small units, the Diesel engine has a very high fuel economy.

(To be continued.)

FORMATION OF GEAR WHEEL TEETH.

To eliminate residual errors in the teeth of gear wheels the Honourable Sir C. A. Parsons, K.C.B., and Mr. S. S. Cook, of Turbinia Works, Wallsend-on-Tyne, propose in a recent patent to grind them with a lap extending a considerable length over several teeth so as to be guided by the average configuration of such teeth. Figs. 1 and 2 are respectively a side elevation and end elevation of a portion of the gear wheel showing a lap in position for grinding teeth. Fig. 3 is a view on an enlarged scale showing the contact between the lap L and the teeth of the gear wheel W. The lap it will be noticed is provided with two handles. It will be seen from Fig. 1 that

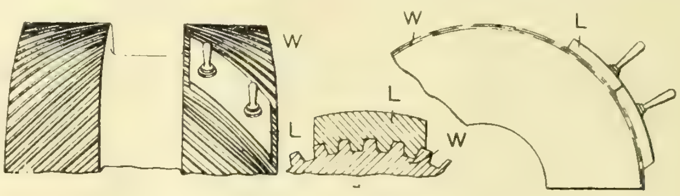


FIG. 1. FIG. 3. FIG. 2.
METHOD OF FORMING GEAR-WHEEL TEETH.

the lap extends over a considerable length of the teeth of the gear wheel, and also over a considerable number of them. To effect the grinding the lap is moved to and fro in the direction of the length of the teeth of the gear wheel, while exerting a suitable side pressure of the lap upon the sides of the teeth. The surfaces in contact are fed with a mixture of oil or other fluid and an abrasive material such as fine carborundum, emery, or glass powder. It is preferable that the lap be formed of an alloy which will cast without contraction on cooling, such, for instance, as an alloy containing 13 per cent. of antimony and 87 per cent. of lead.

CORROSION OF SPECIAL STEELS.

THIS subject was dealt with in a paper by Mr. J. Newton Friend, D.Sc., Ph.D., presented at a meeting of the Staffordshire Iron and Steel Institute at Dudley on Saturday last. In 1850 the yield of pig iron was only about 4,000,000 tons, in 1900 it had increased to 40,000,000, and the estimated production of 1912 was 73,000,000. No one, he ventured to think, could look at those figures without wondering what the end of it all would be, should the demand for iron continue to increase at the present appalling rate, and for how many years could the supply be forthcoming. Owing to the rapid depletion we must look to our own resources, and carefully conserve our stores of iron and steel. This might be done in two ways—namely, by avoiding unnecessary waste in the production of our finished articles, and by preserving those finished articles from disintegration and decay. It was only within comparatively recent years that any serious attempts had been made to determine quantitatively the actual rates of corrosion of various kinds of iron and steel. The author then proceeded to describe some of the best methods of determining the relative rates of corrosion of different samples of steel, and discussed the influence of the physical condition of steel and of alloying elements upon its corrodibility. Like copper, manganese had been sorely abused, he said, as rendering steels liable to rapid corrosion, and there could be little doubt that in this case it was the sulphur that was really to blame. The influence of carbon on the corrodibility of steel was unique, being complicated by a large number of variable factors. From a corrosion point of view the presence of silicon was very desirable, a practically incorrodible metal resulting with 20 per cent. of silicon. Phosphorus, again, in small quantities greatly enhanced the power of resistance of steel to corrosion, but other physical powers imparted to iron by the presence of phosphorus rendered the latter an undesirable constituent for most purposes. The same was, unfortunately, true in regard to silicon.

SOME MODERN METHODS OF WELDING.*

BY THOMAS T. HEATON.

The old blacksmith's method of welding by heating in a coke fire and hammering is well known. It is known also to suffer from drawbacks of various kinds. The heat cannot always be regulated as well as could be desired. Impurities are often introduced into the joint. The weld itself is sometimes found to be defective, that is to say, it is not welded throughout, and the defect may be hidden, as there may be an outside weld of no depth. Great skill is therefore necessary with this class of welding. The methods the author proposes to describe are quite different, and for certain classes of work produce far superior results to any that the blacksmith can attain. Often welds can be made which no blacksmith could undertake.

Broadly, the systems of welding may be divided into two: (1) Electric welding, in which the heat required is produced by the electric current. (2) Gas welding, in which the heat is produced by a gas or mixture of gases. These divisions may be subdivided, as in both cases there are variations both in method and in means.

In electric welding, the chief variations are as follows: (*a*) The electric arc, as in the Benardos system and its variants. (*b*) The system invented by Mr. Arthur Strohmenger, and owned by Messrs Slaughter & Co. (*c*) The contact system, as in the Thomson-Houston method, the Pontelec, the Helsby, and the Allgemeine Elektricitäts Gesellschaft.

The Benardos system, if properly adapted to the work to be done, and with the plant well designed for generating, distributing, and regulating the current, is practical, simple, and effective. It demands a direct current of about 90 volts. The quantity of current used depends on the thickness to be welded, and may in ordinary practice range from 200 to 500 amperes. The work itself forms the positive pole of the arc, and a rod of carbon the negative pole. By this arrangement the greatest amount of heat is in the weld, as the positive pole is the hotter. Where a number of welders are employed, it is necessary that the current shall be supplied in such a manner that one welder shall not affect the arc of another. This is effected very simply by generating in a compound-wound dynamo of ample capacity, and the machine should be slightly over- rather than under-compounded. By this arrangement an increase of load does not lower the voltage. In a well-designed machine the voltage scarcely varies, provided the engine driving it is efficient to maintain its speed. The arcs are arranged in parallel, and each arc is provided with a regulator to adjust the current to the work to be done. The rod of carbon forming the negative electrode is fastened in an insulated holder of light construction. The workman holds this in his hand, strikes the arc by placing the carbon in contact with the work, and manipulates it so as to spread the arc and heat the work at and near the point to be welded with what is described as a soaking heat. When the welding heat is attained, the work is hammered or not, according to circumstances. Screens with coloured glass windows are used to protect the eyes and skin of the workman from the effect of violet rays.

The Zerener process is an arc-welding system which was introduced by Dr. Zerener, of Berlin, some 20 years ago. In this there are two carbons in the same holder, and there is a magnet which deflects the arc produced between these two carbons downward on to the work. No current passes through the work at all. There have been modifications of this system. The object is to maintain a constant voltage in the arc by having a constant length of arc. In the Benardos process the length of arc varies slightly as the workman moves the carbon nearer to or farther from the work. There is, however, in practice, no disadvantage in this.

The Strohmenger-Slaughter system is worked with either direct or alternating current. Alternating is, the author believes, preferred. The voltage is not very high, and its amount, within limits, not important. He has seen 85 volts used with direct, and 220 volts with alternating current, both effective. The quantity of current depends on the work. The parts to be welded are placed in juxtaposition, and an electrode is laid upon and along the welding line. This consists of a soft iron rod covered all over, except at the extreme ends, with a flux which may be constructed chemically to suit the metal to be welded. Contact is made between the work and one end of the electrode, which fuses by a series of arcs along the welding line, melting the electrode into the work and coating the weld with a vitreous flux. It is claimed that this flux prevents oxidisation. It flakes off when the metal cools. This system is interesting. The author understands that it is used with success in the welding of rails and their repair by building up worn places, but he has no experience in it beyond experimental demonstration, carried out to see whether it would supersede efficiently and economically other systems in use.

Electric contact welding is performed by machinery. The Thomson-Houston process was introduced into this country about 20 years ago, and with it the pieces to be welded are fixed in a machine, one immovable and the other in a slide-rest. The piece in the movable slide is pressed by means of the screw against the other, and a very heavy alternating current, the amount depending on the area of the weld, is passed through. The electrical resistance of the joint causes a rise of temperature to welding heat, and the movable piece is pressed forward until a complete union is made. A little hammering is sometimes applied to finish the joint. This system is applied to the welding of hoops for the tyres of cart, &c., wheels, angle irons, and other comparatively heavy sections, and also wire down to small dimensions. The voltage is very low, only about 2 to 4 volts. The current per square inch is about 16,000 to 20,000 amperes.

A more recent method of contact welding is also performed by machinery, but in a different manner, and it is rather delicate in its adjustment as to time and current in relation one to the other. The voltage at the welding point is low, in thin work about 6 volts, and the current, which is alternating, is also low, but the amount depends on the thickness of the pieces to be welded. In this system there are spot welding and roller welding.

In spot welding the work is laid upon a fixed copper contact-piece or electrode. When placed in position, a second (movable) electrode is pressed upon it immediately above the fixed electrode. Current is then switched on, and in passing from one electrode to the other, heats and welds the work. The current is sometimes cut off automatically and sometimes by hand.

In roller welding the system is similar, except that the electrodes are rollers which grip the work overlapped between them, heating and welding it as it travels. This system requires good quality metal; it should be homogeneous, and free from scale or dirt. The adjustment of the time the metal is between the electrodes, and the amount of current required to produce the necessary welding heat and no more within that time, are somewhat difficult to estimate. It is, however, quite a practical system, and can produce most remarkable results in good welding. The greatest care must be exercised to produce these results with regularity.

The spot welds are not continuous and are like a series of rivets without rivet-holes or heads. They can be made continuous by a series of spots overlapping one another. The roller welds are continuous. The Pontelec system is spot welding and is similar to the above. But in this system a small disc is placed between the pieces to be welded immediately between the electrodes, and the disc is crushed down into the weld. It is claimed that this disc tends to concentrate the welding heat at the weld more thoroughly than with the spot welding described in previous paragraphs. This contact welding is very economical in labour for small thin work. It requires skilful attention to keep everything properly adjusted.

In gas welding the heat is produced by a mixture of gas, of more or less good calorific value, with oxygen. The gas is led from its source of supply through a flexible pipe into a burner, held in the hand of the operator, and oxygen is also led into the same burner in a similar manner. The pressure of the gas and of the oxygen is regulated with suitable apparatus. The proportion of gas and oxygen is adjusted by opening or closing their respective inlet valves on the burner, and means are provided in the burner to prevent back firing. The gas and oxygen issue from the burner through a small orifice at the mouthpiece, and are ignited with a match, the proportions of the two being adjusted until a

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* Abstract of paper read before the Institution of Mechanical Engineers, February 20th, 1914.

clear flame shows itself in a fine point. The work it heated by this flame at the welding point, and soft iron (or other metal according to the kind of metal being welded) is melted into the joint to increase its thickness and therefore its strength.

With regard to the gas used for this class of welding, the author thinks the best is acetylene, but other gases are used in conjunction with oxygen, namely, benzol vapour, coal gas and hydrogen, the last being used more especially on the Continent, but acetylene, oxygen, and coal gas can be used together. Acetylene and oxygen, however, form as good and effective a mixture as can be desired. Of the various systems referred to herein, the author regards electric-arc welding and oxy-acetylene welding as the two systems most suitable for general application, and the rest for special work. In some classes of work the electric arc is the more suitable, and in others the oxy-acetylene system, while in some cases both systems are equally applicable. Each is more economical in its own sphere. Owing to the lower temperature, the oxy-acetylene flame is better for thin work than the electric arc, because the risk of burning the metal is not so great. The temperature of the electric arc has been calculated as about 7,500° Fah., but will vary with amount of current. That of the oxy-acetylene flame about 6,000° Fah. (Murray B.O. Co.).

In the author's opinion, the electric heat must be far more effective, however, because it is produced within the work itself, whereas the heat of the gas flame is applied entirely from outside. Where the work is suitable for the electric arc, welds can be made far more quickly than by the oxy-acetylene flame. The proportions of the two gases in welding vary somewhat, but should be in the neighbourhood of 1·5 volumes of oxygen to 1 volume of acetylene. This proportion is given by Mr. Murray, and agrees approximately with the author's own experience in practice. The character of work done varies very largely. The electric arc is used successfully in the repair of steel castings in which, for instance, blow holes may be effectively filled up.

Both systems are used in the welding of mild-steel plates, steel barrels and drums, steel tanks of all shapes and sizes, compressed-air receivers, steam boilers, in their manufacture and in their repair, steam piping and fittings of all sizes, angle and tee irons and other sections; the welding of bosses or flanges into vessels. Receptacles for highly-inflammable and searching liquids are made in many thousands every year for petrol, bisulphide of carbon, acetone, &c., and are quite free from leakage or evaporation. The welds are capable of withstanding high pressures, indeed the author's firm have made welds in gas cylinders which have successfully withstood a pressure of 4,000lbs. per square inch, and welds in mild-steel tube $\frac{3}{16}$in. thick by 1¼in. diam. inside, which have withstood an hydraulic pressure of six tons on the square inch = 20 tons on the metal. They are entirely unsupported as against the pressure. It is clear that these welds must be sound and homogeneous. It is necessary to point out that this is not amateur work. To weld properly and to make the joint sound throughout, skill and training are required, together with knowledge how to apply the system as well as how to design and prepare the work for being welded.

In regard to designing the work for welding there is a wide field, and one serious consideration is the avoidance of internal stresses caused by contraction. These stresses are unavoidable, but their effect may be minimised or nullified by properly designing the shape of the article to be welded. For example, a steel boss has been welded into the centre of a flat circular mild-steel plate ½in. thick, with the result that in cooling radial cracks appeared. It is probable that the material was not of the most suitable quality, but the stresses were indicated. If the same plate had been dished or curved, and of good soft quality, it would have yielded to the stresses, and would have been free from fracture or risk of it. If two plates are butted together, and a third be welded upon them, there is a stress in cooling due to the contraction forcing the butted plates together in conflict with the welds. If instead of allowing the two plates abutting to touch, a space be left between, all stress is avoided. These are examples of design which may be multiplied, and will perhaps serve to illustrate the author's meaning, as they are typical cases.

Much depends on the kind or the quality of the material, which is generally steel or iron. For the generality of this work mild steel made by the Siemens-Martin process or wrought iron cannot be excelled, and the steel should be very soft and low in carbon to get the best results. Bessemer material is not so good, as it varies greatly in the same piece, and therefore often much internal stress exists in it to begin with. The advantage of the kind of welding referred to herein is that, unlike the ordinary blacksmith's work, it is possible to be sure of a sound homogeneous weld. The weld is built up from its foundation, and in most cases can be seen and its soundness and strength ensured, always provided it is properly and intelligently done.

The author has heard the argument advanced that in electric or gas welding the result depends on the individuality of the workman. To a certain extent this is true, as it is true of most mechanical operations. In a weld, however, there is this difference from some other kinds of work, that a defect is not always apparent. With proper training and adequate supervision, however, and a suitable test there is no reason at all why full confidence should not be felt to a much greater extent in electric or gas welding than in blacksmith's welding. To give examples: —

A cylinder of Siemens-Martin mild steel, 20in. internal diameter by ¼in. thick, designed as an air receiver for a working pressure of 100lbs. per square inch, and test pressure of 200lbs. per square inch, was submitted to a destructive test some time ago at the works of the author's firm before an engineer from the Admiralty. The cylinder was 6ft. 9in. long, made in two sections of length united by a welded joint with a butt-strap welded round the cylinder. The two abutting ends of the cylinders joined were kept slightly apart to avoid internal stresses as before described. The ends were

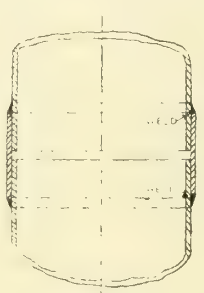


FIG. 1.—OUTSIDE BUTT-STRAP JOINT FOR AIR RECEIVER AT 100LB. PER SQUARE INCH.

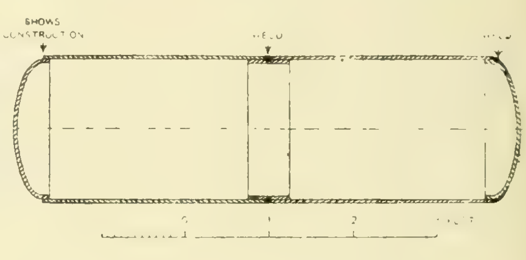


FIG. 2.—METHOD OF WELDING ENDS OF VESSEL TO RESIST INTERNAL PRESSURE; ALSO INSIDE BUTT-STRAP JOINT.

both domed outward to a radius of about 24in., rather too flat, but as specified, and they were ⅜in. thick. Near one end a handhole of oval shape without any stiffening ring was cut out of the body, and a ½in. cover plate put inside with central bolt and bridge piece. At 825lbs. pressure per square inch this cover plate pushed through the cylinder sufficiently to split the body in the solid plate. The part thus split was then cut off and the end re-welded in, somewhat shortening the cylinder, and pressure again applied, until at 975lbs. per square inch one end was pushed out. This cylinder had a longitudinal weld made by the electric arc system for its full length. The two ends were flanged, inserted into the ends of the body, and welded in by the oxy-acetylene process. The method of inserting the ends is indicated by Fig. 2. This method the author considers the best for welding an end into a vessel to resist internal pressure. The form of the end is best suited for the stresses due to the pressure, and by the system adopted any required thickness of weld or rather length of weld can be made. This drawing also shows an inside butt-strap joint. A drawing of an outside butt-strap joint is shown in Fig. 1.

In the course of the test, the circumference of the body permanently increased 2in., or ⅝in. diam. The electric longitudinal weld showed no sign of weakness, but became extended transversely in the circumferential direction. The butt-strap prevented the cylinder becoming stretched in its immediate neighbourhood, so that the cylinder after the test appeared as if it possessed a waist. The effect of the increase in diameter was to tear the body from the ends. The stress on the metal itself just before the end came out was about 17½ tons per square inch. Another cylinder, 6½in. diam. inside by $\frac{3}{16}$in. thick, made of a lap-welded boiler tube, welded by producer gas, in the usual way of such tubes, and with ends

welded in by oxy-acetylene flame, burst at 1,850lbs. per square inch at the producer-gas weld, all else remaining intact.

The author has tested steel barrels by hydraulic pressure with ends quite flat and only 2 mm. thick by $21\frac{1}{2}$in. diam., and they begin to leak at a pressure of about 65lbs. to 70lbs. per square inch. The flat ends push outward so as to tear the weld in this case, which is simply a fused weld made by the electric arc; the ends being flanged, fitted into the body, hooped inside and outside with light steel hoops, and the weld made by fusing the four thicknesses, body, flange of end, and two hoops together, to a depth of about $\frac{3}{16}$in. to $\frac{1}{4}$in. The thickness of body $\frac{1}{8}$in., inner hoop $\frac{1}{8}$in., flange of end 2 mm., and outer hoop $\frac{1}{16}$in. At the author's works there is a vertical steam boiler working at 80lbs. per square inch, and all welded by the electric arc or by gas. Hundreds of boilers have been repaired by both processes, and their lives prolonged for years in consequence. All these examples go to show that these systems of welding are practical, reliable, and worthy of confidence in every respect. Naturally, the character of the metal at the weld is changed to some extent. It loses some of its ductility, and some of its strength, but loses far less than does a blacksmith's weld. Many tests have shown that 89 to 96 per cent. of the original strength of metal can be relied on in the electric weld. It has been said, but quite wrongly, that the electric welding hardens the metal by filling it with carbon from the electrode. This is not the case. For example, in welding mild steel the fierce heat of the electric arc burns out all the impurities, more or less, including carbon, and leaves the metal at the weld purer iron. If any hardening effect has ever been found, it has been due to bad manipulation or to the fact that the metal was never of a properly-weldable quality, or the polarity was wrong.

TABLE I.—*Chemical Analyses.*

Chemical and mechanical tests of acetylene and electrically welded plates, received from Mr. Heaton, of the Steel Barrel Company, Ltd., Uxbridge.—August 27th, 1913.

—	Electrically Welded.		Acetylene Welded.	
	Unwelded metal.	Welded joint.	Unwelded metal.	Welded joint.
	Per cent.	Per cent.	Per cent.	Per cent.
Silicon	0·009	0·003	0·009	0·002
Carbon	0·15	Trace	0·15	Trace
Sulphur	0·025	0·020	0·085	0·071
Phosphorus	0·068	0·043	0·068	0·067
Manganese	0·64	0·27	0·49	0·34
Iron (by difference).	99·108	99·664	99·198	99·520
—	100·000	100·000	100·000	100·000

TABLE II.—*Mechanical Tests on Mild Steel* $\frac{1}{8}$*in. thick.*

—	Electrically Welded.			Acetylene Welded.		
	Un-welded.	Welded joint.		Un-welded.	Welded joint.	
		Trans-verse.	Longi-tudinal.		Trans-verse.	Longi-tudinal.
Elastic Limit Tons per sq. in.	15·20	17·60	Nil.	11·76	11·60	Nil.
Breaking Wght Tons per sq. in.	26·66	24·00= 90%	25·60 = 96%	23·14	18·24= 78·8%	23·20= 100·2%
Contraction of area, per cent.	47·25	Nil.	Nil.	46·66	49·60	Nil.
Extension on 4 inches, per cent.	23·16	5·00	0·50	26·33	13·50	4·25
Extension on 2 inches, per cent.	30·33	7·00*	1·00†	33·66	22·00‡	8·00

* Broke in weld. † Broke outside gauge length. ‡ Broke clear of weld.

Tables I., II., and III. are valuable in that they go to show the effects of the welding upon the metal. For these analyses, drillings were obtained from the plates themselves and also drillings from the welded joints. The plates were tested mechanically, both longitudinally and transversely along the welded joints, and for comparison the unwelded metal. The results of the mechanical tests of the unwelded metal are the mean of three lots. These chemical analyses, and also the mechanical tests, were specially made for the author in August, 1913, by Mr. F. C. Tipler, Chief Chemist, Locomotive Department, London and North western Railway, Crewe. The pieces of material were prepared at the works of the Steel Barrel Company, at Uxbridge, and were of Siemens-Martin open-hearth steel $\frac{1}{8}$in. thick.

One of the strips tested (Table III.) consisted of the original material, and the second one was a piece cut from the same sheet, cut into two and electrically welded at the joint. This material was of a somewhat softer nature than that referred to in Table II.

TABLE III.—*Mechanical Tests on Two Strips of Siemens-Martin Mild-Steel Sheet* $\frac{1}{8}$*in. thick, by Mr. Jenkins.*

—	Breadth of Testpiece.	Thickness.	Area.	Maximum Load. On Piece.	Maximum Load. Per Square Inch.	Extension on 4in. Length.	Reduction of Area.	Remarks.
	Inch.	Inch.	Square inch.	Tons.	Tons.	Per cent.	Per cent.	
1	1.480	$\frac{1}{8}$	0·185	4·06	21·95	32·03	29·63	Original.
2	1·478	$\frac{1}{8}$	0·185	3·59	19·41= 88·428%	10·93	5·23	Electrically welded.

THE THEISEN PROCESS FOR CLEANING GAS.

THE Theisen process for cleaning gas, especially blastfurnace gas, is known by name to most iron and steel men, because Theisen was the first to put a practical washer on the market capable of dealing with the enormous quantities of gas given off by the modern furnace. The first washer was mounted on a vertical axis, but this was soon followed by the horizontal type, of which more than 500 have been built and put in operation. In order to meet modern requirements a new type of Theisen washer has been worked up during the last few years, known as the disintegrator washer. It uses much less power and water, and on account of its efficiency has been very well received. This new type of washer is described in "Stahl und Eisen" for December 18th, 1913, and operating results of various plants are given.

The apparatus is built on the joint-current and counter-current principle. It fulfils in the one machine all the requirements of economic gas cleaning by thoroughly mixing and forcing the gas and water together through the disintegrator arrangement. It also causes the gas to repeatedly strike against suitable washing surfaces, as well as transports the gas and increases its pressure. In the joint-current disintegrator shown in Fig. 1 the gas and water travel from the inside to the outside of the disintegrating arrangement, while in the counter-current type shown in Fig. 2 the gas flows in opposition to the water through the disintegrator from the outside to the inside. In general the first type is used for gas already cooled, while the second is used for hot gas.

The casing of the joint-current apparatus resembles that of a fan. The gas enters from both sides to the middle. On the outside of the entrance passages are the castings containing the ring bearings, through which passes the shaft to the centre of which a cast-steel disc is fastened. On both sides of this revolving disc a cast-steel ring is arranged which bears cylinders of angle iron. Similar rings are fastened to the inner walls of the casing carrying stationary cylinders. The rotating and stationary cylinders are arranged concentrically one inside another. The water for washing is carried through siphon tubes to the interior of a distributing cone on the shaft, which is pierced with holes and provided on the outside with spray plates. Here the water is finely divided, and strikes the first rotating cylinder. The gas and water mixture is then hurled against the recoil surfaces of the stationary cylinder by the centrifugal action, whereby the water is broken up to extremely fine vapour and intimately mixed with the gas. This brings about a thorough moistening of the dust particles in the gas. This action is repeated by the succeeding revolving and stationary cylinders so that

the dust particles in passing through the disintegrator are taken up and retained by the water.

The gas-water mixture is sucked through the disintegrator by the fan blades mounted on the outer part of the disc. The inner part of these blades is inclined and open so that the mixture is hurled sideways against a washing surface built concentric to the fan blades. The water vapour saturated with dust particles separates and moves to the outside as a fluid sheet. The gas is repeatedly forced violently against this sheet of water as in the known and proved Theisen centrifugal washer. The water moving outwards is caught at the edge of the surface in a groove and led away, and because of the arrangement of the groove does not reach to the real pressure blades. This explains the smaller power requirement and the higher pressure produced. The outer part of the fan blades are shaped radially, formed as pressure blades, so that they are closed sideways. They force the highly-cleaned gas to the fan casing, from which it passes under pressure to the mains and the places where it is used.

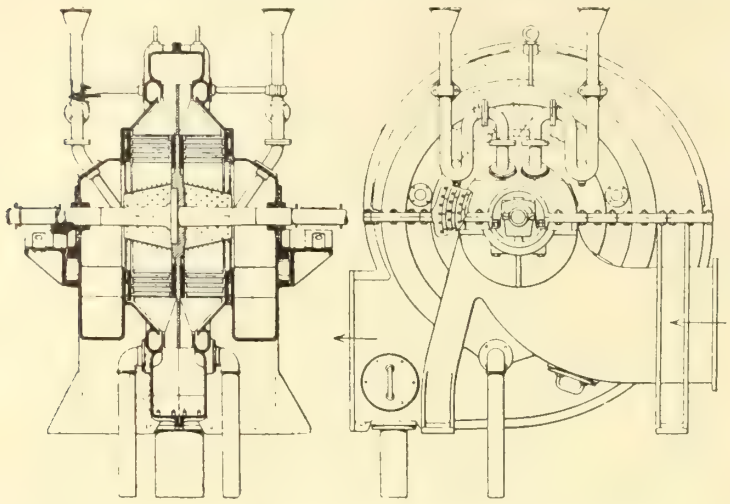


Fig. 1.—Theisen Joint Washer with Disintegrator Construction.

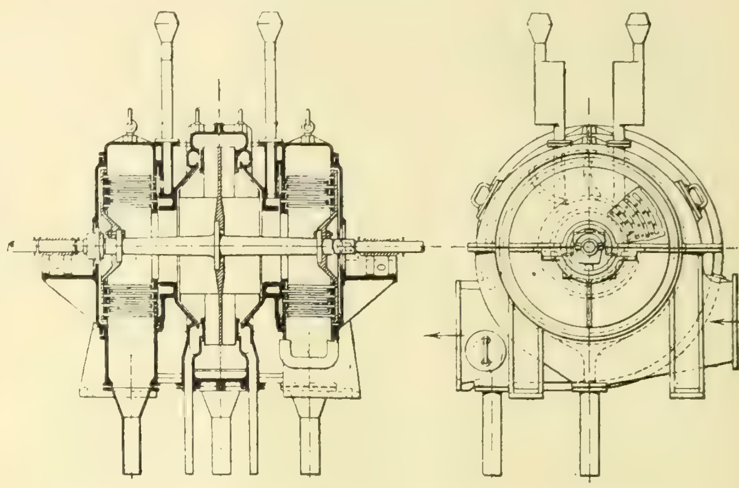


Fig. 2.—Theisen Counter Current Washer with Disintegrator Construction.

previously-described machine. Because of the cooling and cleaning of the gas as it enters the washer, and the counter-current principle, it is possible to deal with hot and very dirty gas without special pre-cooling and pre-cleaning. After passing the disintegrator the gas is subjected to repeated violent impulses against an inclined washing surface as in the other machine. The water is introduced as shown in the diagram, and also sideways to prevent any unwashed gas passing through.

The Theisen disintegrators are reliable, as has been proved by operating records of over a year. All rotating parts are mounted on a common shaft that revolves in water-cooled ring bearings, and is directly coupled to the driving motor. It requires the least space of any gas washer because the cooling, cleaning, and compression is carried out in the same apparatus and with one driving motor. Very little attention is therefore necessary, by no means the constant service of an operator. The wear and tear and oil consumption are also reduced to a minimum, for in the whole apparatus there are only two bearings. No growth of dirt can form because of the powerful washing and rinsing of all parts of the machine. As mentioned before, these points are confirmed by operating results. The fan blades are shaped so as to furnish gas at the pressure required. Theisen water separators are also built to dry the washed gas to the saturation point or lower. They are built on the principle of

Table I.—*Results at Differdingen.*

Amount of gas at 50 deg. C. cu.m.	Gas pressure. In pipe before washer, mm. water.	Gas pressure. Between washer and separator. Mm. water.	Gas pressure. Between washer and separator. Lb. sq. in.	Increase mm. water.	Dust content. Before washer. G. per cu.m.	Dust content. After washer. G. per cu.m.	Dust content. After washer. G. per cu. ft.	Gas temp. Before washer. deg. C.	Gas temp. After washer. deg. C.	Water temp. Before washer. deg. C.	Water temp. After washer deg. C.	Water consumption, litre cu.m.	Total power consumption, h.p. per 1.000 cu.m.	R.p.m.
44.327	-70·5	+130·3	0·185	200·8	1·080	0·020	0·0087	40·0	40·5	30·0	39·3	0·684	5·55	668
47.353	-90·0	+150·0	0·213	240·0	1·000	0·012	0·0052	32·5	33·5	29·0	33·0	0·555	5·43	658
48.515	-85·0	+153·0	0·217	238·0	0·944	0·018	0·0079	33·3	34·5	29·5	33·8	0·550	5·22	649
46.611	-85·0	+158·3	0·224	243·3	0·880	0·008	0·0035	32·5	33·5	29·0	33·0	0·340	5·00	677

Table II.—*Results of Hour Tests at Rombach.*

Amount of gas at 20 deg. C. cu.m.	Gas pressure. In pipe before washer, mm. water.	Gas pressure. Between washer and separator. Mm. water.	Gas pressure. Between washer and separator. Lb. sq. in.	Increase mm. water.	Dust content. Before washer G. per cu.m.	Dust content. After washer G. per cu.m.	Dust content. After gasometer G. per cu.m.	Dust content. After gasometer G. per cu. ft	Gas temp. Before washer, deg. C.	Gas temp. After washer, deg. C.	Water temp. Before washer, deg. C.	Water temp. After washer, deg. C.	Water consumption, litre cu.m.	Total power consumption, h.p. per 1.000 cu.m.
30.252	−30·0	+196·5	0·279	226·5	0·22	0·014	0·011	0·0048	29·0	31·0	27·0	30·4	0·549	4·1
30.312	−22·9	+137·1	0·194	160·0	0·35	0·016	0·012	0·0052	30·6	31·3	26·4	30·8	0·669	4·5
43.050	−55·0	+130·0	0·184	180·0	{0·37 {0·38	0·019 0·018	0·019 0·015	0·0083} 0·0065}	—	—	—	—	0·387	2·9

In the case of the counter-current washer shown in Fig. 2 the gas enters underneath and at once meets the water spray from the disintegrator, so that even in the large gas entrance considerable cooling and cleaning of the gas takes place. The gas then passes through the disintegrator in the opposite direction to the washing water. An intimate mixture and violent agitation of the gas and water takes place as in the

change of velocity and direction, and furnish dry gas, which is very important. Such driers are necessary for all gases that are cleaned by being brought into intimate contact with water.

The first Theisen disintegrator was tested at the plant of the Schalker Gruben und Hüttenverein at Gelsenkirchen in 1909. The results showed a reduction in the dust from 4·0 g. to 0·031 g. per cubic metre (1·75 g. to 0·013 g. per cubic foot). At the Differdingen blastfurnace plant a Theisen disintegrator and water separator has been in operation since 1912 without interruption. It was furnished as a pre-cleaner to lower the dust from 4·0 g. to 0·3-0·5 g. per cubic metre. Due to good pre-cooling, however, the gas only has from 0·88 g. to 1·46 g. per cubic metre as it enters the machine, so that much better results were obtained than guaranteed. Very many tests have been made at Differdingen, the average results of which are given in Table I. Based on these results Theisen has built for Differdingen large disintegrators for 50,000 cub. m. per hour capacity (1,765,700 cub. ft.), furnishing clean gas at 0·54lb. per square inch.

At the Rombacher Hütte at Rombach there are two Theisen disintegrators each of 30,000 cub. m. hourly capacity. One has already been steadily in operation for 14 months, and the other was started about June, 1913. This apparatus should clean the gas to from 0·1 g. to 0·2 g. per cubic metre with a maximum water consumption of 0·7 litre per cubic metre. Very exact tests were carried out, the results of which are given in Table II. No. 2 machine did not produce so high a pressure because a washing surface was built concentrically around the fan. The increased power consumption is partly due to this cause and the fact that more water was used. The surface was later taken away because the required cleanness was more than reached without it. The temperature measurements show that with gas and water entering at almost the same temperature the outgoing gas is slightly hotter, due to part of the energy being changed to heat. Three more Theisen washers, each of 45,000 cub. m. per hour, have now been installed.

Illustrations are given in the original paper of one of two similar machines of 40,000 cub. m. to 45,000 cub. m. hourly capacity that have been in operation since the beginning of 1912 at the Hasper Eisen and Stahlwerke. The dust is reduced from about 2 g. per cubic metre to 0·017 g. to 0·018 g. per cubic metre. The results are given of a disintegrator applied to pre-cooled producer gas. The tar was reduced to 0·2 g. to 0·4 g. per cubic metre from an original of 45 g. The results are also given of a small machine at the Krupp Rheinhausen plant used for blastfurnace gas. Finally, figures are given from an Austrian plant that uses a Theisen machine in a strictly comparative manner with a Schwartz-Bayen disintegrator, the results being greatly in favour of the former.—"The Iron Age."

ELECTRIC FURNACE FOR COPPER ALLOYS.*

BY G. H. CLAMER.

THE development of the Herning furnace has been progressing favourably. Being a departure in design, much of the necessary data for the best proportions had to be obtained by actual trial on furnaces themselves, as it did not exist in books and tables; among this data were a number of physical constants which are beyond the ranges given in tables. Moreover, the data had to be obtained on a practical scale as distinguished from a laboratory scale. Development work of this kind requires running a furnace to destruction in order to find out its weak points.

Briefly, the furnace is of the resistance type (that is, not an arc furnace); the metal is heated, like the filament in an incandescent lamp, by passing the current through what might be termed a thick filament, or column, of the liquid metal. The furnace itself consists of a hearth, having two, three, or four cylindrical holes in the bottom, which are closed at the far ends by the electrodes. These holes may be vertical, horizontal, or preferably inclined upwards into the hearth, and, of course, are filled with the molten metal of the hearth.

By means of the electrodes, the electric current is then made to pass through the columns of metal in these holes, thereby heating very rapidly. The proportions are made such that all the heat of the furnace is generated in the metal in these holes. In addition to thus heating the metal, the current also exerts a peculiar force by means of which it circulates the metal rapidly in these holes by forcing it out into the bath and sucking fresh liquid metal into the holes; hence the heat of the furnace, which is originally set free in the holes, is rapidly transmitted to the bath of metal in the hearth, and in addition a most thorough mixing and stirring occurs. It is this circulating force, popularly known as the *pinch effect*, which is the basis of the furnace and which makes such a method of heating possible.

Cold metal is melted by immersion in this heated bath. The hearth is kept closed, thereby avoiding any loss of zinc vapours. It is opened only while cold metal is being inserted. Moreover, the space in the hearth above the metal can be kept neutral or even reducing, whereby all oxidation is prevented. The furnace can be made tilting if desired, as the transformers for the electric current are attached permanently to the outside. As the walls may be made thick, the furnace gets only slightly warm on the outside, even after continuous running night and day. The furnace itself is simple in construction, and the only perishable part, the hearth and heating holes, are easily renewed when worn out. Brass, bronze, copper, lead, iron, steel, ferro-silicon, &c., have been melted in it repeatedly. It has been run day and night continuously without any undue overheating in any parts.

The development has been effected with small furnaces of about 25 kw. to 30 kw., and has been greatly retarded by the transformers not giving their rated capacities, for which, of course, the furnaces were not responsible. Being only small furnaces the loss of heat per pound of metal was necessarily greater than it would be in a large, well-built, commercial unit. Moreover, much heat was lost through the top, which was only crudely closed. No particular efforts were made in these tests to economise the heat, as it will readily be seen that this can be done effectively in a large, properly-built furnace, and involves no difficulties, depending merely upon how thick one is willing to make the walls and cover. The recent development had to do chiefly with finding the best form and proportions of the water-cooled electrodes and the best dimensions of the heating holes, on which latter the effectiveness of the circulation through them so greatly depends; the greater this circulation the smaller the furnace for a given duty.

Notwithstanding that no particular efforts were made to economise the heat losses, the results were favourable considering the small size of the furnace, and the fact that the transformer could not supply more than about half of its rated output for which the furnace was built.

Ordinary yellow brass was melted repeatedly, including superheating, at a rate of about 8·7lbs. per kilowatt-hour. Considering the abnormal losses in the transformer and the fact that no special efforts were made to economise the heat losses, the furnace being frequently opened at the top, these results are considered quite favourable. With conservative estimates, it is thought that this figure might be increased to 10lbs., and probably more. The figure for theoretically perfect operation is not known definitely, but is believed to be about 14lbs.

At 1 cent per kilowatt-hour, this would, therefore, mean about 10 cents per 100lbs. However, it is not proper to compare this figure directly with the fuel cost for melting brass in the usual combustion furnace, as there are other factors of equal or even greater importance which should also be included. Among these is the reduction in the loss of zinc, which in the fuel furnaces sometimes involves an even greater cost than the fuel cost. Concerning the loss of zinc in the furnace, the best indication that there is practically none is that there is an almost entire absence of any white fumes coming out of the furnace. The only loss of zinc by white fumes was from the thread of metal as

* Paper read at the Chicago Meeting of the American Institute of Metals.

it was being poured out, and this, of course, cannot be avoided in any furnace. There is, furthermore, no loss of metal by spattering; all the metal that is put into the hearth must come out, without loss, as melted metal. There is no loss by oxidation, as the atmosphere in the furnace may always be made reducing with a little charcoal. The losses by combustion with sulphur in the fuel gases are, of course, also entirely absent. The saving of the losses of metal, therefore, are of great importance, and in some cases might alone pay for the cost of the electric power.

The wear on the lining in a brass furnace has been found to be so slight that this cost of relining, per 100lbs. of metal, will undoubtedly be almost insignificantly small. As to what the saving in labour cost will be has not yet been determined, but there is not any question that the labour cost will be considerably reduced, as will also the foundry floor space per ton per day, as these furnaces may to advantage be forced, hence may be made to give a relatively greater output per day. It has been shown that there is no difficulty whatsoever in getting the required high temperature, for by simply leaving the metal in the furnace a little longer the temperature will rise to any amount desired.

The fact that the liquid metal is continuously circulated upward, like boiling water in a kettle, brings all mechanical impurities, gas bubbles, &c., including no doubt also the sulphides and oxides, to the top, leaving the metal pure. With a blanket of charcoal over the top, some of the oxides might even be reduced.

The furnace, of course, may be made tilting, as all those under construction now are, and they may, if desired, be made to tilt around the lip, thereby facilitating the pouring directly into ingots or moulds. Copper has been easily melted repeatedly in these furnaces. This was one of the unexpectedly favourable developments, because copper has such a low electrical resistance that resistance furnaces for copper have heretofore been impracticable. In the present furnace the proportions of the heating holes for copper do not become impracticable, though it was feared at first that they might be.

One of the chief and most difficult parts of the furnace to develop was the water-cooled electrodes connecting the transformer with the melted metal in the bath. A successful form of construction of these parts has now been devised and tested out, and has given entire satisfaction. It also has been found that the circulating force may be made much greater than was at first supposed, and this makes the design proportions of the heating tubes more favourable, and reduces the size of that portion of the furnace. This circulating force was in one test so great that the liquid metal rose about an inch above the surface, where it was squirted upwards; the velocity was so great that at times drops of metal were thrown off at the surface by this rapid evolution, though not enough to spatter the metal. If a suitable pyrometer exists to be placed into the heated metal, it is possible to regulate the temperature with great precision, thereby avoiding both under and overheating

In a small 10 kw. furnace, what is known electrically as the power factor was accurately measured, and was found to average about 95 per cent., which is greater than was expected, and is practically perfect. In a larger furnace a crude measurement gave about 85 per cent., but it is believed that the instruments may have been somewhat in error and that it was probably higher.

Fatal Flywheel Accident.—Through the failure of a flywheel at the Codnor Park Ironworks of the Butterley Company, on the 17th inst., one man was killed, and at the inquest which was subsequently held, it was stated that the primary cause of the accident was an undetected flaw in the main shaft to which the flywheel was attached. The engineer at the ironworks said that the flaw could only be seen after the machinery was stripped, and it was questionable whether it could be seen on the surface. They had not the least reason to suspect a flaw. The jury returned the usual verdict of "Accidentally killed."

THE ADVANTAGES OF MECHANICAL CONVEYORS.

At a meeting of the Institution of Engineers and Shipbuilders in Scotland, recently held at Glasgow, Mr. Heinrich Ollendorf read a paper on "The Utilisation of Ground Adjoining Harbours and Railway Stations by the Aid of Mechanical Conveyors." The author explained in detail and with the assistance of lantern slides the plans on which harbours and railway stations are constructed, and showed how mechanical conveyors could be used economically. It appeared, he said, that for distance traffic proper, when the land conditions were simple, the wire ropeway could not compete with the railway, which was available for all sorts of goods and for passengers, and, therefore, had better economy. But for short distances the railway freights per train mile increased very rapidly on account of the great cost of loading the trains and the high wages paid to those in charge of trains. It was otherwise in the case of the wire ropeway, the expenses of which were about the same for all distances longer than six miles, and only slowly increased below that figure. The reason for the small cost of the wire ropeway lay in the small amount of friction, which required comparatively small expenditure of energy. Besides, the loading of goods took place by the aid of hopper fillers, and by employing the weight of the loads to move these automatically the presence of a driver on the spot was not needed. Curves and intermediate stations raised the cost of the wire ropeway, especially when the land was built upon, but, under just these conditions, it had a special advantage over the railway, since it was only with the greatest difficulty that the latter could be adapted to the purpose, and it was sometimes impossible to use a railway when the land was fully built on. In these matters private enterprise was in advance of municipally-worked concerns. Private enterprise had shown that an industry often renounced the advantage of lying close to the water, and was content with efficient transporting arrangements, when these were not too dear, to connect it with the waterway. But there seemed no reason why municipalities should not improve on their past efforts and follow in the path which private enterprise had shown to be so profitable, and construct harbours with few docks, to be fully utilised by being connected with the cheaper land adjoining by means of transporting arrangements of the most efficient kind.

CORRESPONDENCE.

Testing Accuracy of Drills and Lathes.

To the Editor of "The Mechanical Engineer."

Sir,—I shall be obliged if any of your readers would be so kind as to favour me with their assistance in answering the following questions: (1) Describe how you would test the accuracy of a radial drilling machine. What degree of error would you allow in a new machine made to drill up to 2in. diam.? Describe the measuring instruments you would use in the test as above. (2) How would you test the leading screw of a lathe for accuracy? What degree of accuracy would you expect to find in a new screw?—Yours,

A. T. H.

Dangerous Railway Couplings.—In his report on a collision at Possilpark Station on the North British Railway on December 23rd, when an up express train from Fort William to Glasgow collided with a part of a mineral train belonging to the Caledonian Railway, Major Pringle comes to the conclusion that the division of the mineral train was caused by the breakage of a link which was not of the latest (Gedge) pattern. It was welded at one of the ends instead of in one of the long sides, and the fracture occurred at the welded end. The fractured surface showed defective welding of the wrought iron over nearly two-thirds of the exposed section. The attention of railway companies had, he states, been drawn on other occasions to the advisability of providing additional strength to wagon couplings by the use of steel instead of wrought iron. The existence of wrought-iron links of this old pattern constituted a real weakness and source of danger to railway working. Having regard to the heavier loads now worked by goods trains, and to the number of divisions which occur, the question of strengthening the drawing arrangements of wagon stock was of increasing importance.

INDUSTRIAL AND TRADE NOTES.

Orders for Destroyers.—Orders for two torpedo boat destroyers for the British Admiralty have just been placed. Messrs. Hawthorn, Leslie, & Co. Hebburn, have received an order for one and Messrs. J. S. White & Co., Cowes, are to build the other.

Manchester Ship Canal.—During the past year the tonnage and receipts of the Canal were the largest on record, and as a result the company has been able for the first time to pay a return of $2\frac{1}{4}$ per cent. on the $3\frac{1}{2}$ per cent. preference stock held by the Manchester Corporation.

German Locomotives for a British Railway.—The South Eastern and Chatham Railway Company have placed an order for ten powerful locomotives with Messrs. A. Borsig, engine builders, of Tegel, near Berlin. The engines will be built to the specifications of the chief mechanical engineer of the railway company. The reason for placing the order abroad is not, it is stated, a question of price, but entirely a question of delivery. The German firm have undertaken to deliver the ten engines by the end of May.

Regulation of the Welsh Tinplate Output.—It is understood that the proposals to curtail the output of tinplates recently discussed at successive meetings held by the makers at Swansea were definitely adopted at a further meeting held a few days ago. It has been agreed that the production is to be 15 per cent. smaller than that for the previous quarter, the curtailment to commence on April 1st. The working of the arrangement will be confined to the regulation of the production only, being on a similar basis to that ruling in the galvanised sheet trade.

A Quarter's Railway Accidents.—A Board of Trade report just issued states that the total number of persons killed on railways in the United Kingdom during the three months ended September 30th last was 304, as compared with 276 in the corresponding period of 1912. The total number injured was 2,213, as compared with 2,329. Amongst the killed were 54 passengers, 107 servants of companies, and 15 other persons who met their deaths by accidents or passing over level crossings. There were also 118 trespassers (including suicides) and 10 others killed whilst on business at railway stations, &c.

The Trades Disputes Act.—An influential meeting of employers convened by the Employers' Parliamentary Council was held in London on the 18th inst., when a resolution was unanimously carried calling upon the Government, in view of the continued and growing menace to personal freedom, public order, and industrial peace due to the provisions of the Trades Disputes Act, to set up an enquiry into the working and effects of the Act, and to determine whether certain amendments in regard to picketing, &c., should not be made. Sir Richard Temple presided, and employers were present from all parts of the United Kingdom.

Rebates in the Steel Trade.—The English Steelmakers' Association has, we learn, decided to continue the rebate system, despite the opposition. It may be recalled that the scheme, which provided for a rebate of 5s. per ton to consumers who confined their purchases to the Associated Makers, was inaugurated in October, 1911, and abandoned by the Scottish steel makers in November last. Although some important consumers have seceded from the arrangement and threatened to buy their supplies abroad and form an independent makers' association, the Associated Makers apparently consider themselves strong enough to maintain the rebate.

A Large Die Press.—One of the most striking exhibits in the engineering section at the Anglo-American Exposition, which is to be opened next May at the White City, Shepherd's Bush, will be that of a gigantic die press, which is being sent over by the Ferracute Machine Company, of Bridgeton, New Jersey. This enormous piece of machinery, which stands some 30ft. high, will cost several thousand pounds to bring over and to erect, and will be shown in actual operation. Large, flat sheets of metal will be placed in the machine, and with but two movements it will stamp out a full sized automobile body. Some idea of its hugeness may be gathered from the fact that there is standing room for 50 men in and about the framework and mechanism of this colossal piece of machinery. The same firm will also exhibit a similar piece of machinery which at a single stroke stamps out seamless metal baths.

The Panama Canal and Trade Developments.—In a lecture on "The Panama Canal," delivered at the Birmingham University, Prof. Kirkaldy, in dealing with the commercial effect of the canal, said its completion would open up American and European civilisation in a way that had not hitherto been possible. Ships leaving the Eastern States of North America and the North western ports of Europe would be able to take emigrants and goods to the ports of the North western States of South America, which were at present in a more or less primitive state. There had been a disinclination to emigrate to the western side of South America, although it was fertile and rich. The local effects of the canal were likely to be very considerable; distances would be reduced and there would be great increase of trade. There had been much discussion as to the extent British trade would suffer when the Panama Canal was opened. Some people in America had felt that the opening of the canal would be the means of America ousting Great Britain from the lucrative trade she now enjoyed. Compared with English traders, Americans were prepared to supply coal at ports in the neighbourhood of the canal at a reduction in price of between 30 per cent. and 50 per cent. America was able to produce coal cheaper than Great Britain, because the country was more up to date in mining methods. In Great Britain mining methods had to be modernised; while parties were quarrelling over a 5 per cent. or a 10 per cent rise in wages they might eventually kill the goose that laid the golden egg. This was a question of national importance.

Scientific Management.—At the monthly meeting of the Production Managers' Association, held in London on the 11th inst., the president, Mr. W. Howard Hazell, who has just returned from a visit to the United States, gave an address on scientific management and how to apply it to businesses. The average opinion of the average man seemed to be that the system might suit other people's business, but it would certainly not suit his own. It was revolutionary to consider the new methods when compared with the old ones. The originator of the system was Mr. F. W. Taylor, and he had been engaged for the past 23 years in working it out. He had begun with the problem of turning steel in lathes, and for years had been timing the different methods and trying to determine the best. There was one way, and that the best way to do any work, and an efficient workman with proper tools should do this work in a certain standard time. The time-study man took a process or a machine, and studied it. First he divided it into as many operations as he thought suitable. Then he took the average time taken on the particular processes. He often spent three or four weeks studying a process, making changes to see if they were improvements. He would set a standard time in which the process should be done. The workpeople are paid the usual weekly wages, and in addition, a bonus based on the standard time allowed for the different processes, and those who get nearest to the standard were paid the highest wages; thus 100 per cent. efficiency was usually paid time and a third for the time worked. Finally, there was the planning room, in which all the work was schemed, which workman was to do the job, what machine it was to be done on, and what the standard time for the job should be. The idea of the system was not to lower wages, but to increase them, and to increase the output for the same floor space and the same plant. Something like 50,000 workers in the United States were working under the new system, and the number was increasing. This system held great advantages, as it was only by becoming efficient producers that they could maintain their hold on foreign markets.

Opportunities for Trade in the Russian Far East.—According to a report by H.M. Consul at Vladivostok the trade of the United Kingdom with Vladivostok has always been insignificant, and in 1912 it was, as far as can be judged, rather more so than usual. The most unsatisfactory feature of the position is that it is impossible to see how, under present conditions, any material improvement can take place. United Kingdom firms have no footing in Vladivostok, and, in face of the businesses which have been built up by old concerns which have grown with the country, would start at a disadvantage in establishing themselves. It is only by working on some principle of combination of different producing interests that any serious result could be achieved; otherwise, the initial expenditure and the cost of organisation would be prohibitive. The country is a new one, and it has no manufactures. It is, therefore, dependent upon outside sources for satisfying all the needs of a population which is not large at present, but which is rapidly increasing in numbers and purchasing power. Galvanised iron, corrugated and flat, remains, as it always has been, the staple import of United Kingdom manufacture. In addition to galvanised iron a considerable quantity of black sheet roofing iron, some portable engines, a few boat motors, and some casual machinery were imported from the United Kingdom. Central heating apparatus is more and more used, but in this article it would be hard to compete with the Germans. Hardware and tools of United Kingdom manufacture, in view of their high quality, should be able to compete to some extent with the German articles. They are at present almost unknown. Machinery of all kinds is imported, Germany being the country of origin of probably 80 per cent. of it. Agricultural machinery is the branch which shows the greatest capacity of development. Oil tractors have quite recently been introduced for ploughing, and are attracting very

great interest, and their use is certain to spread. United Kingdom firms making a perfected type of oil or steam tractor might profitably follow up this matter. Boat motors, motor-cars, and lorries are also in demand to an extent which is worthy of attention. Sawmill machinery, oil mills, and flour mills are in request. The first is at present entirely supplied by Germany; the other two by Russia or Germany. A good British type, if well introduced, should find a fair sale. In correspondence with local firms the Russian language should, whenever possible, be employed; German is fairly widely known, but English is very little used. Of the small number of travellers representing British firms who find their way to Vladivostok hardly any have a knowledge of the language of the country; the consequence is that they are obliged to rely upon indifferent interpreters, and are thus very heavily handicapped.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1912.

Utilisation of peat. Rigby, Testrup, & Wetcarbonising, Ltd. 25146.
Couplings for pipes, rods, and shafting. Barber. 29991.

1913.

Internal-combustion engines. Aslatt. 258.
Brake and reversing gear. Horsley, and Daimler Company. 2480.
Large capacity feed-water heater. Soc. Anon. pour la Construction de Réchauffeurs d'Eau à Grand Volume. 2496.
Machines for concentrating and separating ores. Wynne. 2564.
Apparatus for measuring and recording the flow of fluids. Paterson. 2569.
Apparatus for measuring vapours, gases, and liquids. Liese. 2597.
Superheaters. Stenning. 2685.
Valve mechanism for internal combustion and like engines. Thomas. 2763.
Mechanical lubricators. Hine. 2792.
Carburetters for internal-combustion engines. Senemaud. 2794.
Clutches. Senemaud. 2795.
Double-acting four-stroke cycle engines. Frederickson & Stenger. 2896.
Clutch mechanism. Hensmans. 2909.
Ash ejectors for ships. G. & J. Weir, Ltd., and Petermöller. 3176.
Machine for rolling metal bars of cruciform or other section. Strathern. 3301.
Automatic temperature regulator with adjuster and indicator. O. M. Hemple and Fink. 3321.
Steam traps. Justice. 3345.
Apparatus for softening or purifying water. Anderson. 3504.
Methods of raising and forcing liquids and apparatus therefor. Joy. 3653.
Motor-road vehicles. Mellersh-Jackson. 3765.
Machine for cutting and flanging circular sheet-metal plates. Siddle. 4122.
Four-stroke-cycle internal combustion engines. MacDonald. 4342.
Speedometers. Perrot & Matthew. 4754.
Carburetters for internal-combustion engines. Welsh, and Thomson-Bennett, Ltd. 4789.
Carburetters for internal-combustion engines. Mumford and Boothroyd. 4911.
Governing of internal-combustion engines. Blackstone, Carter, and Carter. 5107.
Process and apparatus for producing tungsten in malleable form. Canello. 5150.
Internal-combustion engines. Neute. 5722.
Manufacture of driving belts. Rudge-Whitworth, Ltd., Pugh and Blair. 6718.
Slotting, shaping, and planing machines. Liebert. 6978.
Connecting rods for multi-cylinder internal-combustion engines. Boyle, Boyle, Redrup, & Redrup. 7111.
Rotary pumps. Allan. 7126.
Apparatus for scraping fuel economisers. Green & Tansley. 7765.
Carburetters for paraffin. Pink & Holloway. 7767.
Apparatus for effecting intimate contact of liquids and gases. Kirkham, Hulett, & Chandler, Ltd., and Hersey & Blake. 7958.
Frictional-locking hydraulic clutches. Rich. 8025.
Portable drills. Wade. 8292.
Lubricators for pneumatic or other fluid-operated tools. Wakefield. 9500.
Valves for air compressors and pumps. Taylor. 9764.
Forging of crank shafts. Fairweather. 10703.
Internal combustion engines. Daucher & Favorit Vergaser Ges. 11660.
Combined couplings and valves for fluids. Esse & Greathed. 12150.
Smokeless combustion of fuel in boiler furnaces. Gruenwald. 12315.
Cooling vaporisers and combustion chambers of oil engines. Crossley & Webb. 12321.
Cutter holders of coal-cutting machines. Eckersley. 12380.
Fuel injectors for internal-combustion engines. Moussiaux. 12811.
Blastfurnace and other tuyeres. Burnyeat, Moncur, Sibbald, and Lochhead. 13838.
Mechanical forging hammers. Comhaire. 14148.
Device for preventing accidents in coal and other mines due to over winding. Wilson. 14195.
Lever mechanism for transmitting rotary motion. David and Williams. 15015.
Manufacture of chains. Theile. 15848.
Magneto-electric ignition apparatus for internal-combustion engines. Hardingham. 16566.
Method of treating steel and iron in the manufacture thereof. Gostling. 17869.
Reversing gearing. Anderson & Slater. 18646.
Rotary compressors, exhausters, and blowers. Sang. 19570.
Producing peat fuel or coke. Prioleau & Prioleau. 20668.
Manufacture of steel car wheels. Keithley. 20747.
Internal-combustion engines. F. E. Baker, Ltd., and Baker. 20750.
Rotary pumps. Siemens Bros. Dynamo Works, Ltd. 20789.
Worm-drive for motor-vehicles. Morton. 21937.
Lathes. Ryder. 26675.
Micrometer gauges. Rivoal. 26781.

ELECTRICAL, 1913.

Electric controllers. British Thomson-Houston Company. 2418.
Electrical switches. William McGeoch & Co. and McGeoch. 2758.
Magnetic separators. Bowes, Scott, & Western, Ltd., and Dalgleish. 3046.
Electric measuring instruments of the thermal type, Everett and Edgcumbe. 3110.
Electric motors particularly adapted for hoisting purposes. Otis Elevator Company. 3250.
Apparatus for heating liquids electrically. K. P. H. Syndicate, Ltd., and Kratt. 3370.
Magazine arc lamps. Brockie, and Johnson & Phillips, Ltd. 4926.
Electric arc lamps. Engineering & Arc Lamps, Ltd., and Dowdell. 8301.
Electrical fuses of the plug type. Paiste. 15760.
Method of insulating electrical conductors. Heany. 18517.
Magneto-electric ignition machines for internal-combustion engines. Anschutz. 22527.
Electricity meters. Korting & Mathiesen Akt.-Ges. 27877.

METAL QUOTATIONS.

TUESDAY, FEBRUARY 24TH.

Aluminium ingot	86/- per cwt.
,, wire, according to sizes, &c. ......from	112/- ,,
,, sheets ,, ,, ... ,,	112/- ,,
Antimony	£27/10/- to £29/10/- per ton
Brass, rolled	7½d. per lb.
,, tubes (brazed)	9⅝d. ,,
,, ,, (solid drawn)	8¼d. ,,
,, ,, wire	7⅝d. ,,
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The Mechanical Engineer.
An Illustrated Weekly Journal. Vol. 33, No. 841.

Edited by
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Telegrams: "Scientific," Manchester.
Telephone No. 6655 City.

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Autogenous Welds in Boiler Repairs.

THE current issue of "Vulcan" gives some illustrations taken from the report of the Brussels Association for the Inspection of Steam Boilers which are very instructive as showing the dangers that may arise from the indiscriminate use of autogenous welding in vessels subject to internal pressure. For a multitude of purposes autogenous welding is exceedingly useful, and is extensively applied in connection with boiler repairs. There are, however, limits to its application, and we know of many cases where it has been applied to remedy certain kinds of defects such as grooving, and where subsequent working has shown that it was a palliative and not a cure, inasmuch as the repair did not relieve the stresses which were the primary cause of these defects. On the other hand, it has been extensively employed to compensate for wasting due to corrosion with very good results. It is, however, more particularly in the making of ordinary forged welds that autogenous processes call for supervision and judgment, since it may be so easily resorted to to cover up bad construction or bad workmanship. In the illustrations shown in our contemporary one of the square boxes of a superheater had not been forged as it ought to have been out of a solid drawn round pipe, but had been constructed out of two angle bars united along their edges with autogenous welds, so as to form a rectangular box of square section. According to the report the development of some defects led to the box being taken out and tested. The results were rather startling. The writer of the report says that after disconnecting a short branch, which had been autogenously welded on, by a single blow from a sledge hammer, "we commenced to hammer lightly on the anvil one of the angles at the end of the square section of the main box. After several blows this connection became detached, and it was found that the welding was only effective over a very small fraction of the nominal thickness of

four millimetres. At the same time, the weld connecting the two angle pieces gave way, where, again, it was found that the weld was only good over a fraction of the thickness. Another box, which had also been taken out, was then hammered at one of the welded angles near the middle of its length, and after about 20 light blows, it was observed that although the welding appeared to hold good at the part hammered, it gave way at both sides of that part." The report adds, in conclusion, that the weld apparently "never connected more than a small part of the thickness, although, viewed on the inside, drops of spilled metal were visible, which made it appear as though the whole thickness had been covered by the welding." The danger of too great a reliance on autogenous welding is obviously recognised by the boiler inspecting authorities in Belgium, which are under Government control, for a Ministerial circular has been issued which "forbids the use of autogenous welding in the construction of boilers or in extensive repairs."

Advertising for Engineering Services.

A STRONGLY-WORDED circular letter has been addressed by the Institution of Civil Engineers to its members calling attention to a practice pursued by certain local authorities when engineering schemes are under consideration. It appears to be customary for them to advertise in the Press requesting engineers to submit their terms for preparing plans and proposals, accompanied, then or at a later stage, with estimates of the cost of the works, the authorities in question evidently regarding such professional service as they would a contract for materials. The action of the Council in condemning such a proceeding, not only as undesirable, in the best interests of the public authorities themselves, but as derogatory to the engineering profession, will, we are sure, be supported by every fair-minded person who gives impartial consideration to the matter. The value of professional engineering services cannot, like material goods, be measured in feet and inches or pounds avoirdupois, and attempts to do so must inevitably degrade the service. If a quoted price for such work is to replace qualifications and experience, as the practice implies, unscrupulous candidates in such a competition begin to think of doors leading to other practices which compensate for any sacrifice of remuneration they may make to secure the work, and which more honourable men would disdain. In a word the practice is a temptation to the inefficient and weak practitioner and a handicap on the well-qualified and independent one, and we are glad that the Council have not hesitated to express publicly the repugnance they feel with regard to it. We trust, too, that their intimation of the action they have taken to the Local Government Board may not be without result in bringing home to the public authorities who have resorted to the practice in question an adequate sense of its iniquity, and further, that every member of the Institution will support the Council in declining to respond in any way to such advertisements as those alluded to.

Emergency Hospitals for Industrial Works.

WE have had on many occasions to comment upon the reckless disregard of life and limb that has in the past characterised industrial life in the United States, and it is therefore but meet that we should bear equal witness to the generous and even lavish manner in which many of its large industrial firms are now endeavouring to reduce not only the risk of such injuries by better supervision and the equipment of safety appliances, but also to minimise the inevitable suffering when accidents do occur. In our last issue we drew attention to the remarkable improvements in the safety of working of locomotive boilers which had followed from the institution of a system of State inspection. Since then we have received the December Bulletin of the American Iron and Steel Institute, which is devoted to an illustrated account of what are termed in the States industrial emergency hospitals, and which are now being erected there in many large works for the purpose of rendering efficient first aid in the event of injury to workmen. In conjunction with these hospitals first aid squads recruited from the working staff are trained to give assistance similar to that rendered by members of the St. John's Ambulance in this country, and which often proves so valuable in diminishing the suffering of patients pending the treatment of their injuries at a skilled centre. If this is at any distance it is a serious handicap, for in numerous cases prompt attention at the hands of a skilled surgeon greatly facilitates recovery, while lack of it may cause a comparatively minor injury to end fatally. For this reason travelling, even under the best conditions, is in many cases objectionable. Obviously even the smallest hospital equipped with modern appliances and having a skilled surgeon and nursing attendants is an expense that can only be borne by large industrial corporations, and America offers more opportunities and probably has greater need of them than this country. Be that as it may, the illustrations and descriptions in the Bulletin of a number of emergency hospitals which have been erected in connection with various large steel and iron works bear testimony to the exceeding thoroughness with which they have been schemed and equipped, everything being of the most up-to-date character as regards sterilisation, X-ray apparatus, and all the other refinements of latter-day surgery, so that an injured workman is assured of receiving prompt and highly-skilled assistance without the risks incident to transit over a long distance, and with the assurance that, if necessary, he will not be called upon to endure this until he can do so safely.

SMOKE-WASHING PLANT FOR LOCOMOTIVES.

To meet the requirements of the smoke abatement ordinances of Chicago, the Lake Shore and Michigan Southern Railway has recently equipped its roundhouse in that city with a smoke-collecting and washing system, and we are indebted for the following particulars and illustration of the plant to our American contemporary, the "Railway Review." In arranging the plant provison was made for dealing with the stack gases from about two dozen locomotives. The smoke duct is arranged in the roof trusses of the building, as shown in Fig. 2, and is made of "Transite," this material being selected because of its imperviousness to the corrosive action of the gases emitted from the locomotive stacks. Connecting with the main duct, which varies from 3ft. diam. at the extreme ends to 6ft. at the washer, are a series of 24in. branches, one for each stall, which connect with the locomotive stacks through the medium of telescopic jacks. The weight of the latter in each case is counterweighted by means of a lever to the outer end of which, near the wall of the building, is a line reaching down to the floor, and by means of which the jacks can be lowered to make a close connection with the stack, or may be lifted therefrom as required. Operating in harmony with the raising and lowering of the hood is a damper which closes off the uptake when same is not in use, thereby improving the quality of the induced draught through such other jacks as may be in use.

The gases collected by the smoke duct above referred to are drawn through a motor-driven exhausting fan, which in turn forces them through a triple discharge pipe, the termini

of which are below water level in inverted tubs or hoods. These hoods are so arranged that the gases, in reaching the stack, must pass through a water bath which acts to remove

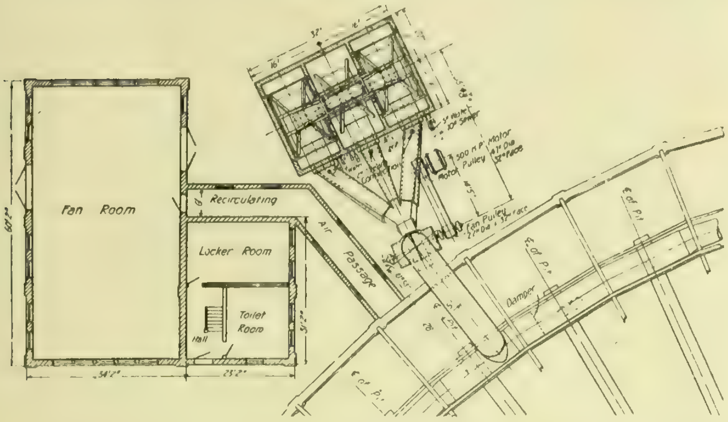


FIG. 1. PLAN SHOWING RELATION OF SMOKE-WASHING PLANT TO ROUND HOUSE AND HEATING PLANT.

the solid matter, as well as portions of the objectionable fumes, before allowing them to reach the atmosphere. From the illustration, Fig. 3, it will be seen that the washing apparatus consists of a concrete vat or tank 22ft. by 32ft. outside dimensions. Concrete partitions divide this tank transversely into three compartments of approximately equal size. A branch of the discharge pipe is led into each of these compartments. The water in the tank being maintained at a higher level than the tops of these pipes, the gases are brought into intimate contact therewith. After this initial immersion they enter into an inverted tub whose edges are likewise below water level, and to escape which they must again pass through the bath. Escaping the inverted tub they are collected by means of a hood, the edges of which also extend down into the water in each of the three compartments, and are thereby conducted through a 60ft. stack to the atmosphere.

To facilitate the close intermingling of the gases and the water, live steam is blown into the discharge pipes at points near the entrances to the tank in such quantities as to keep the water, with the aid of the pressure of the gases themselves, in a state of violent agitation. Water is admitted to each of the three compartments as needed through a 3in. line, and likewise a 6in. drain to the sewer is provided in each case. At one end of the vat is an overflow also connecting with the sewer. The smoke duct, beginning shortly after it leaves the fan, the hoods, and other parts within the tank and likewise the stack are of wood construction, it having been found advisable to substitute wood for steel as was used in the early experiments, owing to the better acid resisting qualities of the former material. In the stack is placed a series of baffles, the purpose being to arrest as much as possible any tendency of the condensation to be carried out with the gases.

In the course of a day's operation with from 20 to 22 engines in the roundhouse, an average of about 10 barrels of residue is skimmed off the surface of the water in the vat. This is placed in barrels having perforated bottoms, allowing quantities of the moisture to drain off, after which, with the residue approximately dry, the contents of the 10 barrels can be reduced to the volume of three, which, at 50lbs. per barrel, results in the collection of something like 150lbs. of solid matter each day. Analysis of this material has shown: Carbon 82·6 per cent., sulphur 2·6 per cent., water (in combination) 3·9 per cent., iron oxide 8·7 per cent., silicon 1·[illegible] per cent., other materials 0·4 per cent. While no commercial disposition of this product has as yet been arranged for, the matter is being investigated, and it is anticipated, among other things, that use can be found for it as a paint pigment, it being over 80 per cent. pure carbon, or lampblack.

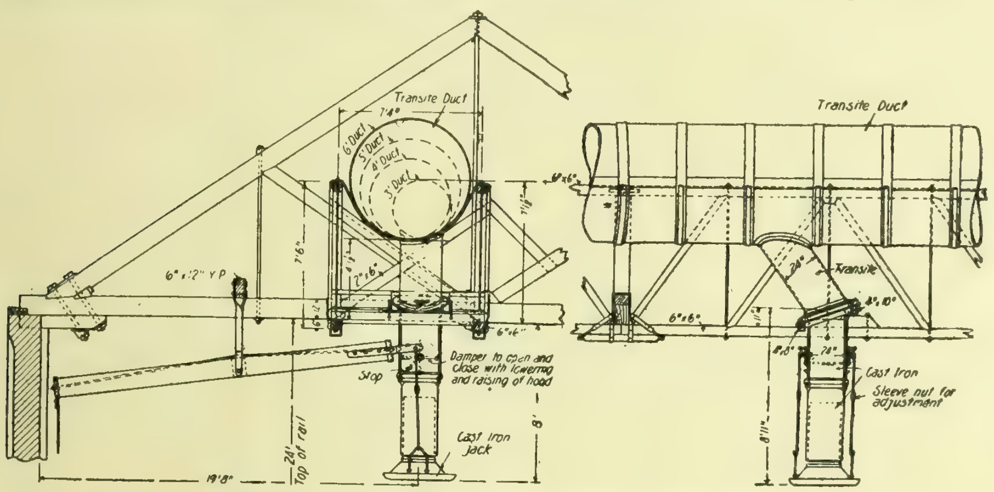


FIG. 2.—ROOF STRUCTURE SHOWING POSITION OF SMOKE DUCT.

Aside from complete success in eliminating smoke and the possible utilisation of the by-products of this process, the expense of construction and operation of the plant is neutralised to a considerable extent by virtue of the fact that engines can be and are fired up without the use of the blower. Experiment has shown that it takes from 750lbs. to 900lbs. of steam, involving the burning of about 150lbs. of coal, to get up steam on the average locomotive. With this expense taken over by the smoke-washing system, the cost of operating the latter is diminished in proportion to the number of locomotives fired up, which at many terminals would amount to a very considerable item.

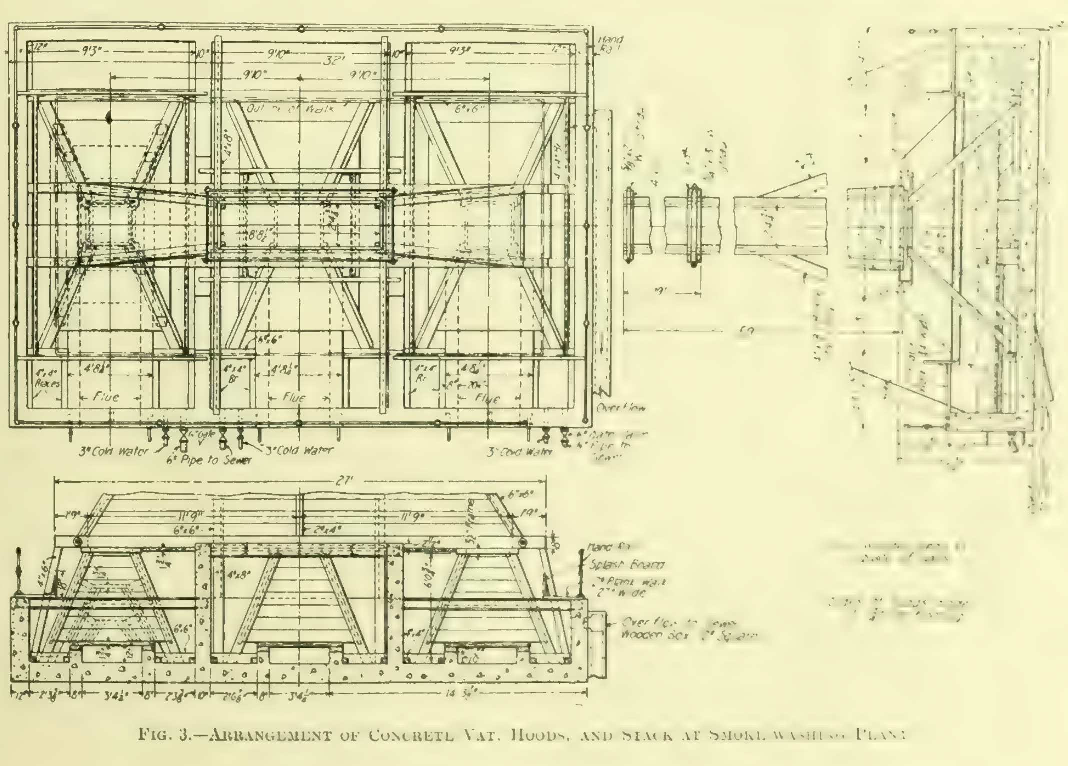


FIG. 3.—ARRANGEMENT OF CONCRETE VAT, HOODS, AND STACK AT SMOKE-WASHING PLANT.

BREAKDOWNS OF STATIONARY ENGINES.*

BY MICHAEL LONGRIDGE, VICE-PRESIDENT.

(*Concluded from page 190.*)

Pistons and Piston Rods. — Previous to 1899 breakdowns originating in pistons averaged 2·5 per cent. of the total breakdowns. Since then the average has been 4·8. The rise came suddenly soon after the rise of steam pressure to 160lbs., but I do not know that there is any connection between the two.

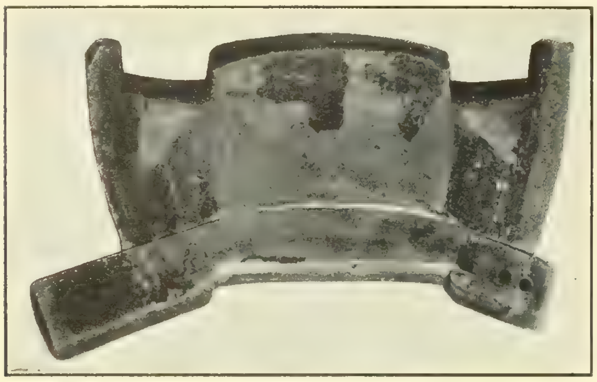


Fig. 15.

During the last three years 47 per cent. of these breakages have been caused by stray screws, or bolts, or broken rings, 17 per cent. by water, and the rest in various ways. When the substitution of plain pistons, with cast-iron rings strung into grooves, for pistons with junk rings and fancy packings is complete, breakdowns from piston breakages will be halved.

Breakages of piston rods occur nearly always at the cotter-holes at the cross-head end, and are due to concentration of stress at the edges of the cotter-holes, as explained by Dr. Unwin on page 223 of Part II. of his "Machine Design," 1912 edition. I endorse his explanation, and Figs. 15 and 16 afford convincing proof that cotters do bend in the way indicated by the drawing in his book. These figures are from photographs of two pairs of folding-wedges from the piston rods of two old beam engines after exhibitions of water in the cylinder. I would have shown single cotters, such as are generally used, but I, unfortunately, have none by me at the moment; moreover, I am not sure that folding-wedges are not preferable to single cotters, because a piece with parallel sides is easier to fit accurately than a tapering wedge; but if they be used, it is clear that the position of the pieces shown on the screen should be reversed, the broad piece should bear on the rod, and the narrow on the crosshead.

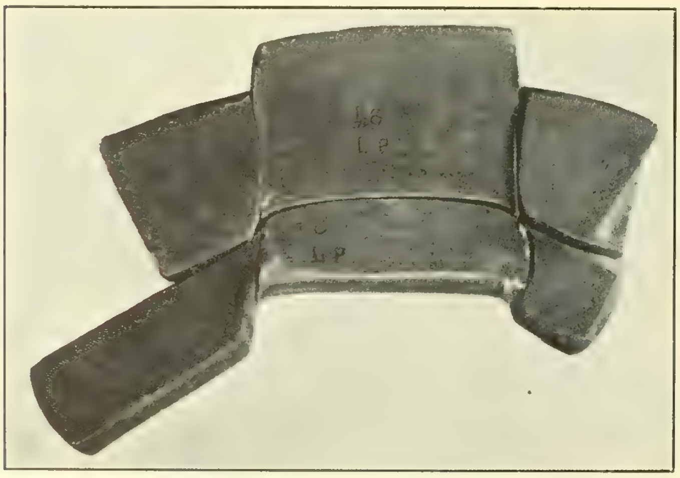


Fig. 16.

Connecting Rods. — Fractures in connecting rods occur generally at the ends which couple the rods to the crank pins, or crosshead centres; sometimes in the forks, when the crosshead ends are forked; and rarely in the bodies of the rods. The commonest types of end are the box end or closed eye, Fig. 20; the open strap secured by jib and cotter, Fig. 19; and the marine end with cap and bolts, Figs. 17 and 18. Of the three the marine end, Figs. 17 and 18, is, in my experience, the least safe, because of the frequent breakages of the cap bolts, usually at the junction of the head and shank, or at the screw thread. The principal causes of these breakages are repetitions of stress or blows, abrupt changes of form, cross-bending stresses produced by the inertia of the rods. The antidotes are, for the first, probably spare bolts, to give alternate periods of rest and service. Annealing is risky in unskilled hands. For the second, large fillets at junctions of heads and shanks, gradual reductions of diameters in shanks, and threads with rounder roots than the British standards; but fillets, cones, &c., at changes of section must be very neatly finished where they merge into the cylindrical parts, and threads very carefully chased, especially in steel, to leave nothing in the nature of cuts or scratches to initiate cracks. Also stiffer palms and caps are often needed to prevent deformations, which would be apparent on reference to an india-rubber model, and consequent concentration of stress on one side of the bolt.

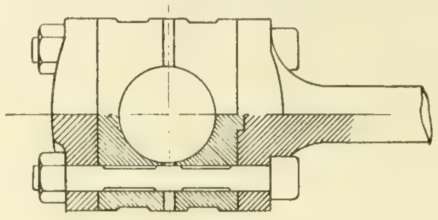


Fig. 17.

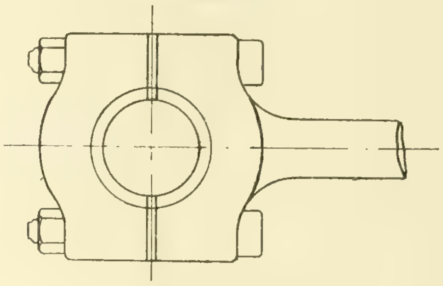


Fig. 18.

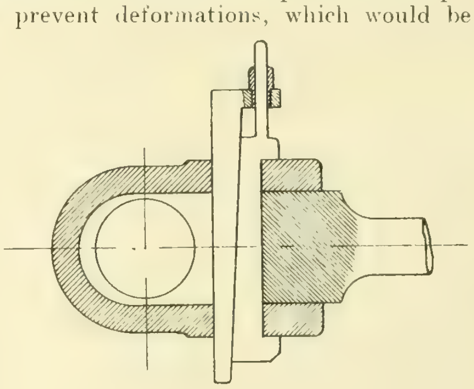


Fig. 19.

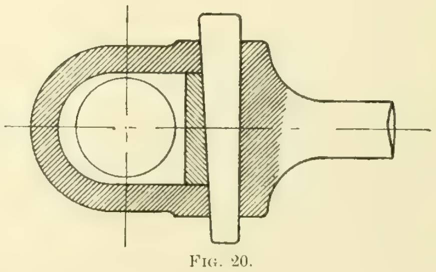


Fig. 20.

For the third, bolts with *areas* instead of *diameters*, approximating to half those of the rods, and the substitution of jaws, Fig. 18, long enough to hold at least one of the brasses, for palms, Fig. 17. Rods like Fig. 17 should be taboo, for it is easy to imagine the effect of a cross-bending stress if there be any wear or slackness. Bolts of small engines are more heavily strained by this stress than large, because the ratio of their length to their diameter

* Lecture delivered before the Graduates' Association of the Institution of Mechanical Engineers, on February 9th, 1914.

cubed is greater. For connecting-rod bolts wrought iron is a safer material than steel. Open straps, Fig. 19, secured by jibs and cotters are but little safer than marine ends. The jaws of the cotters wear, the straps open under the cross-bending stress produced by the inertia of the rod, and break, generally through the oil hole. Fracture almost invariably begins on the inside surface, and when it has extended a certain distance, often not far enough to be visible above the flange of the brass, the strap breaks and opens out. Never trust a strap till you have seen the inside surface. Open straps should be kept closed on the butts of the rods by bolts in place of, or in addition to, the jibs.

Of the three forms, the box end, Fig. 20, is undoubtedly the most reliable. Fractures, when they occur, usually commence, as in the straps, on the inside surface at the hole for the lubricator, but extend slowly enough to be discovered before the rod gets free. Among more than 6,000 breakdowns of engines of various kinds I can only find one where fracture of a wrought-iron or steel box-end caused damage to an engine, and this was the fault of the engine-tenter, for the fracture had been visible on the outside surface of the end as far as the lubricator hole some time before the rod gave way.

Crank Pins.—The history of crank pins has been very like that of cylinders, showing a rising percentage of breakages culminating in the five years 1894-1898, and then falling. The rise was due to bad designing, improper methods of fixing, and overloading; the fall to the more general adoption of the right method of fixing, combined with reduction of stress. In my early days stresses of 12,000lbs. to 14,000lbs. per square inch were common, and stresses of 50 per cent. higher were frequently met with. Samples of the old designs and methods of fixing are shown in Fig. 21. In Fig. 21 A, B, C, and D are examples of pins with conical or cylindrical shanks fitted into the cranks and secured by riveting, screws and nuts, or cotters. They usually broke inside the crank-eyes, because the fit was not accurate enough to prevent slight movements, which wore and enlarged the ends of the crank-eyes next the journals, thus throwing back the point of support and increasing the bending moments. It will be noticed that the pins were put usually in from the faces of the cranks, so that they could come out and wreck the engine when they broke. E and F are also typical examples. They have not sharp corners at the junctions of the journals with the collar, though such were not unusual; but the fillets provided, $\frac{1}{16}$in. to $\frac{1}{4}$in. radius, are too small to be effective. Both pins were of steel. The fractures were due to bending stresses. They commenced at the parts of the circumference nearest to, and furthest from, the crank shaft, and extended inwards, as shown on the shaded part of G, Fig. 21. The lives of these pins were $14\frac{1}{2}$ and 104 million revolutions, and the bending stresses 17,500lbs. and 11,500lbs. per square inch respectively.

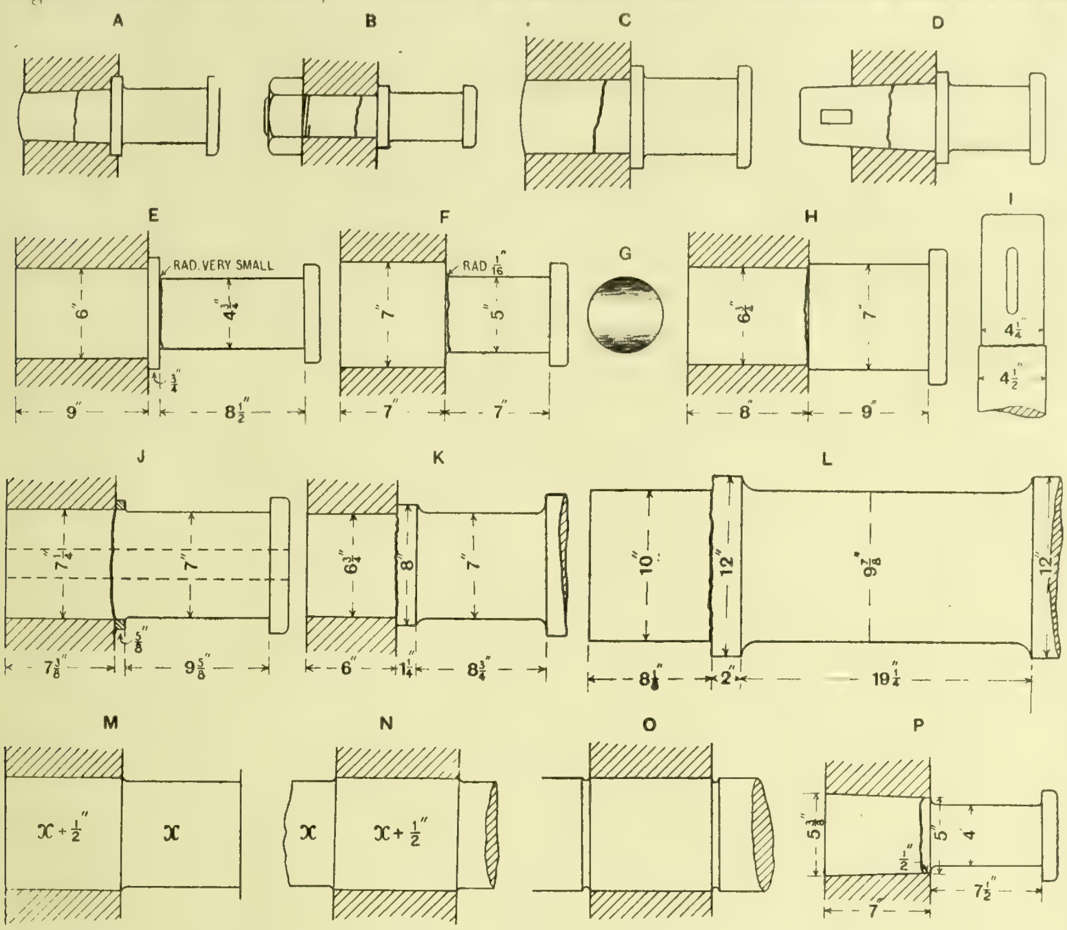
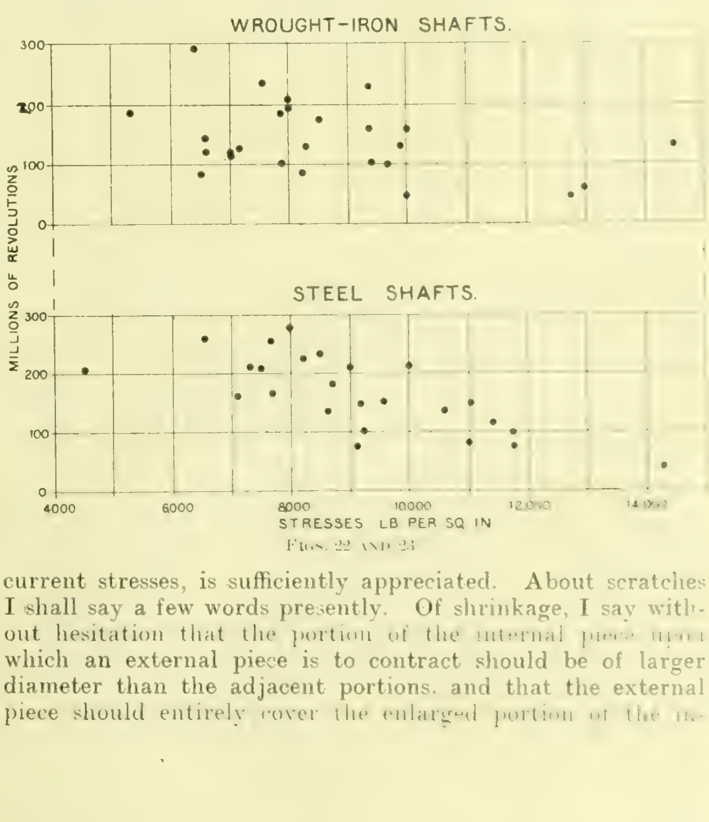


Fig. 21.

The breakage of H may have been entirely due to the abrupt change of diameter from $6\frac{3}{4}$in. to 7in., for piston rods in direct tensile stress will break with a smaller change than is shown at I, Fig. 21; but probably it was started by the shearing action of the edges of the crank eye when cooling and contracting upon the pin. The failure of the pin J can be attributed to nothing else but shear. It was made of steel, of 60,000lbs. tensile strength, $29\frac{1}{2}$ per cent. extension in 6in., 60 per cent. contraction of area, and a strip, cut out of it after the breakdown, was bent cold nearly double without cracking. It broke under a stress of 9,400lbs. per square inch, after $5\frac{3}{4}$ million revolutions. I think the crank shafts K (Fig. 21) and L are similar cases. The stresses and lives were: For K, 8,200lbs. per square inch and 17 million revolutions; and L, 5,000lbs. per square inch and 218 million revolutions; the longer life of L was due to the lower stress, and probably to a lower pressure exerted by the crank in cooling. I do not think the effect of the pressure of sharp edges, or even of scratches in starting skin-cracks in steel, or the almost inevitable extension of such cracks under re-



Figs. 22 and 23.

current stresses, is sufficiently appreciated. About scratches I shall say a few words presently. Of shrinkage, I say without hesitation that the portion of the internal piece upon which an external piece is to contract should be of larger diameter than the adjacent portions, and that the external piece should entirely cover the enlarged portion of the in-

ternal. M (Fig. 21) shows how a crank pin should be put in, while N and O show the proper method of shrinking a piece upon a shaft. It is to the adoption of this principle by many engine makers, combined with reduction of working stress to 8,000lbs. or 9,000lbs. per square inch, that the reduction in

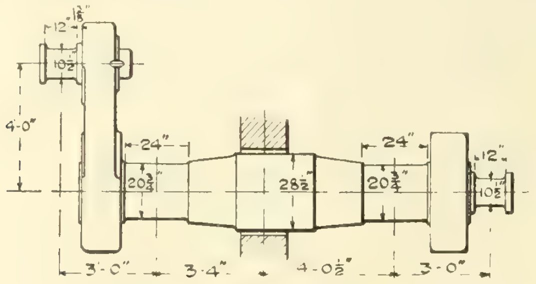


FIG. 24.

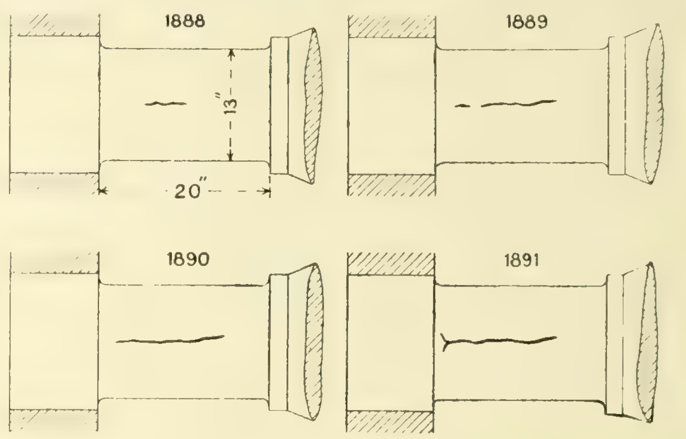
the number of crank-pin breakages must be attributed. The failure depicted in P is one of those things "no feller can understand."

Crank Shafts.—The majority of mill engines have plain shafts with overhung cranks carried in two bearings. In 1879 these shafts, except a few old ones of cast iron and a few new ones of steel, were of wrought iron. Now nearly all are of mild steel. I think most of the breakages may be ascribed to gradual disintegration by wear and tear, and vibration of spur gearing, or to the extension of small flaws or cracks existing in the interior of the shaft when new, or developed upon the surface afterwards by chilling it when hot. The duration of life measured in revolutions of the engine undoubtedly bears some relation to the stress, but it is uncertain what this relation is. I have been able to get fairly reliable information about a certain number of broken shafts, and from it I have plotted the points shown on the two diagrams, Figs. 22 and 23. Fig. 22 refers to wrought iron, Fig. 23 to mild steel shafts. In both, the abscissæ represent stresses calculated by Rankine's formula, and the ordinates length of life in millions of revolutions of the engine. Beyond a general tendency to abbreviation of life by increase of stress, the spots show nothing, and I fear the effects of repetitions of stress are here, and in similar statistics always will be, obscured by the other causes of breakage I have mentioned, and the difficulty of getting accurate information about shafts which have worked for many years.



FIG. 25

I would like to describe a few breakages of crank shafts. The first case is one of the disintegration of a cast-iron shaft by wear and tear. The dimensions of the shaft are shown in Fig. 24. It belonged to a pair of beam engines, and was put in, with them, in 1850. In 1900 there were several slight longitudinal cracks in both necks, and in the left-hand neck one 14in. long, which was said to have been visible for twenty years. On April 7th, 1910, this neck got hot, and the mill had to be stopped to allow it to cool. On April 8th it ran hot again, and was examined in the evening, when, besides the 14in. crack, 24 other well-defined cracks of various lengths, up to 5½in., were visible, all longitudinal in direction and situated near the middle of the bearing. It then transpired that the neck had been hot in 1908, and had been cooled with water. It was therefore doubtful whether the cracks were more than surface cracks caused by the water; but having regard to the age of the shaft, its replacement was advised. The decision was justified when the shaft was broken under the tup. The fractured surfaces, shown in Fig. 25, did not coincide with any of the longitudinal superficial cracks, but were transverse and diagonal. The new and white fractures were caused by the tup, while the dark old fractures, blackened by oil, were very considerable in extent, and showed the disintegration of the interior of the shaft by age and wear. The right-hand neck showed similar black and white areas when broken. Some particulars of the



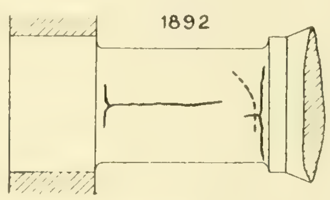


FIG. 26.

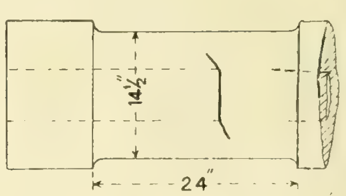


FIG. 27.

life of the shaft, so far as they could be ascertained, may be of interest:—

	1850 to 1873.	1873 to 1897.*	1897 to 1910.
Millions of revolutions	70	76	41
Initial load on piston .. .. lbs.	90,000	56,500	51,000
Bending stress on neck, lbs. per sq. in.	3,650	2,270	2,050
Load on piston at cut-off	76,500	36,800	33,960
Bending stress equivalent to bending and torsion by Rankine's formula lbs. per sq. in.	3,750	1,930	1,580

*Mill stopped one year during this period.
Total life, 187 million revolutions. Average stress, 2,700lbs. per square inch.

Fig. 26 shows the gradual destruction of a wrought-iron shaft 28 years old, during the last four years of its life. The first crack, probably the opening of a cinder mark or imperfect weld in the forging, was seen in the left-hand neck in October, 1888. The development during the following three years is shown in the figure. In 1892 it had further extended, and there was also another crack in the right-hand neck, of the development of which I have no record. The cracks shown by the full lines are on the part of the circumference furthest from the crank pin, those shown by the dotted lines on the part nearest the crank pin. The stress in the shaft was 8,500lbs. per square inch, and the life 123 million revolutions.

When speaking of crank pins, I referred to the effect of scratches or skin cracks upon steel, and I want to illus-

trate this point. Fig. 27 shows the crank shaft of a pair of McNaughted beam engines running at $32\frac{1}{2}$ revs. per minute. After the shaft had worked nine years, a very interesting crack appeared in one of the necks, as shown in Fig. 27. For a length of $5\frac{1}{4}$in. it was absolutely straight, without the jagged edges a crack usually presents, and followed the line of a circumferential scratch, such as might have been made by a knife held against the revolving shaft. At either end it branched off diagonally for a length of $2\frac{1}{4}$in., each extension having the normal appearance of a crack. I marked it with

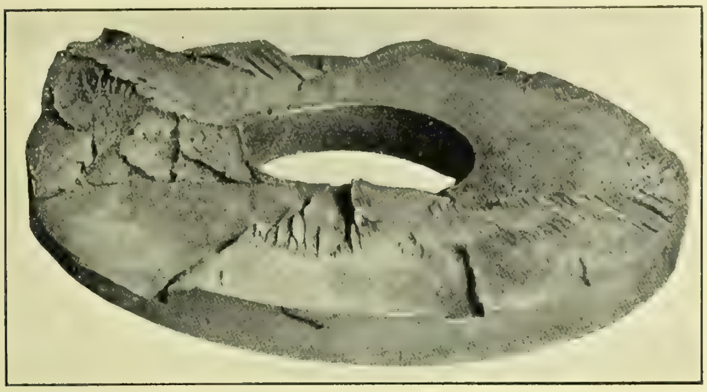


FIG. 28.

a centre-punch, and let the engine run on It ran on for four months, and then the crack began to extend so rapidly that the shaft was thought to be unsafe, and was replaced. The stress on the neck was about 7,500lbs. per square inch, and the life of the shaft only $51\frac{1}{2}$ million revolutions.

Fig. 28 shows a piece cut from the neck of a steel shaft, after the shaft had been broken by a tup. The shaft was probably new in 1893. The neck was $13\frac{1}{2}$in. diam. and 26in. long. Test pieces cut from the broken shaft gave a tensile strength of 25·7 tons per square inch, a yield point of 14·3 tons per square inch, an elongation of $40\frac{1}{2}$ per cent. in 2in., and a contraction of area of 60·3 per cent. In 1905 the neck was free from cracks, but in 1908, when the next examination was made, there were a number of fine marks like scratches, principally in a circumferential direction, as clean as if cut with a knife. One in particular, about 7in. from the fly-wheel end of the neck, was 18in. long. As the marks were so fine and clean, it was hoped that they were nothing more than scratches, or, at most, skin cracks brought out by heating, and as the shaft was very lightly stressed, only about 4,500lbs. per square inch, it was allowed to run on. A few days later, however, the engine had to be stopped, as black oil appeared inside the bore. The long crack was then found to have extended almost continuously round the neck, following one or other of the circumferential scratches. Fig. 29 shows a piece broken off the shaft and magnified about four times, which clearly shows how the small surface scratches were eating into the steel. The cause of the scratches could not be ascertained.

Spur Gearing.—About 1879, when horizontal engines of 800 i.h.p. to 1,200 i.h.p. began to replace beam engines of half that power in cotton mills, when pitch-line speeds were rising from 1,800ft. to 2,300ft. pr minute, loads on teeth from 10,000lbs. to 18,000lbs., and gear ratios from $2\frac{1}{4}$ to 1 to 3 or $3\frac{1}{2}$ to 1, an epidemic of breakages of spur gear set in. Some 20 per cent. of the engine breakdowns were breakages of spur wheels on engine crank shafts, and the pinions driven by these wheels broke almost as frequently. Many of these breakdowns were due to irregularities of pitch, twisted teeth, sinuosities of pitch circles, concentration of pressure on the end of teeth through movement of the crank shaft, backlash from the momentum of rope drums on second-motion shafts, and other faults of workmanship and use common to old-pattern moulded wheels and to old engines. But the damage was not confined to these. Many new wheels, as good as mechanical skill could make them, with teeth moulded by machinery, spur runs cast in complete circles, and machined internally, carried on crank shafts held in pedestals, with brasses adjustable horizontally as well as vertically, broke also.

These breakages were usually attributed to "vibration," "wear and tear," "teeth bearing up to points," and similar effects of a cause ignored or not discerned. That cause, in my opinion, was the use of teeth too long and too wide to "correspond with their environment," the most important fact of that "environment" being the unavoidable motion of the engine crank shafts on which the driving wheels were hung.

I will try, with the aid of Figs. 30 to 33, to make this clear. Fig. 30 represents three teeth A, B, C of a spur wheel geared with three teeth D, E, F of a pinion. The teeth are supposed to be cycloidal, for involute teeth have not found favour with makers of main driving gear. Their length is exaggerated to make this illustration clear. Similar profiles can be set out, according to the rules in the books, to provide three points of contact, x, y, z, and three teeth to carry the load. They look very pretty upon paper, but they will not work if the spur wheel A B, C be forced towards the pinion D, E, F by the motion of the shaft. The contact at y ceases. The pressure is taken off B and concentrated upon the points of the teeth C and D, and there intensified enormously by the forcible retardation of the driving wheel or acceleration of the pinion. And even if the crank shaft could be held absolutely steady, the same effect might be produced if the teeth came from the mould full at the points, or if the pitch-line had proud places, both common defects in uncut wheels. If, however, the faces of the teeth were cut away sufficiently to limit the contact to the immediate neighbourhood of the pitch point y, the motion of the wheel towards the pinion would simply cause the tooth B to slide on E without strain or change of angular velocity. And of all intermediate positions of the point of contact it may be said that the further it moves from the pitch point the more destructive become the effects of shaft displacements, incorrect tooth forms, or sinuosities of pitch lines, and conversely the shorter the path of contact the less the mischief resulting from these unavoidable irregularities. Experience has led millwrights to the same conclusion, for they invariably set out wheel teeth so fine at the points and roots that they bear on only near the pitch line when new, and when through wear the bright bearing surfaces extend to the points of the teeth, they chip the points to avert the damage just referred to.

The question is, why do they leave surfaces which are not used when the teeth are new and which have to be chipped off when the teeth are old? I never could get a

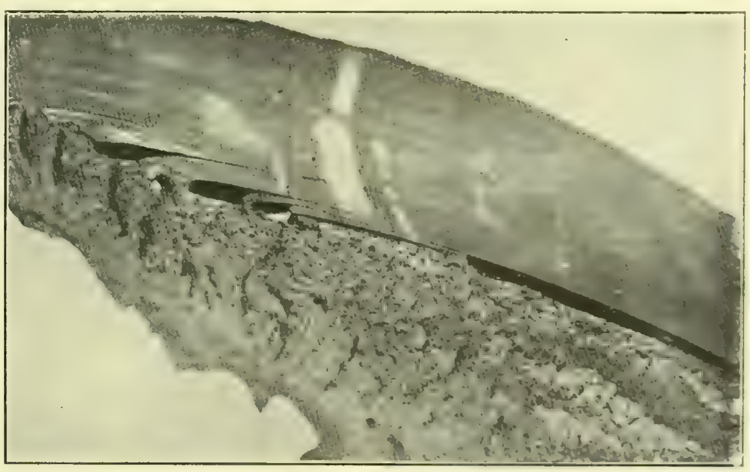


FIG. 29

satisfactory answer. Neither, as far as I know, would wheel makers cut short their teeth till 1888, when a firm of engineers consented to make a pair of wheels with short teeth, Fig. 31, for their own shop engine. These wheels must have felt like the first lady who appeared in public minus a crinoline, so greatly did they differ from the fashion of their day. They had 49 and 47 teeth, $2\frac{5}{8}$in. pitch, $\frac{15}{16}$in. long, and $4\frac{1}{2}$in. wide, the ratio of length to pitch being 0·36. With fixed centres and accurate moulding teeth $\frac{1}{4}$in. long would have kept contact. These wheels held their grease well and ran smoothly till the engine was replaced in 1892.

They were but small, and running at a low speed (1,080ft. per minute), but they were more convincing than arguments or drawings, because they were made of cast iron and could be seen at work.

Figs. 32 and 33 show what they accomplished in a few months. The former shows the teeth of a wheel and pinion put in in November, 1888, after two other sets of gearing had been destroyed in the space of eleven years. The teeth were $4\frac{15}{16}$in. pitch, $3\frac{3}{4}$in. long, and 19in. wide, while the distance between the centres of the shaft bearings was only $66\frac{1}{2}$in. With these dimensions and a pitch-line speed of 2,410ft. per minute, the motion of the crank shaft threw the whole load of 16,400lbs. upon the corners of the teeth and drove the points of the pinion teeth into the flanks of the wheel teeth with jar and vibration sufficient to break one of the segments in the following March. Then more teeth were cracked and more segments broken, and it became necessary to replace the entire rim. The new rim was made of steel, with teeth of the same pitch and breadth as the old, but $2\frac{3}{16}$in. instead of $3\frac{3}{4}$in. long, Fig. 33. They would have been better $1\frac{1}{2}$in. long. The tooth of an engine driving wheel is a cantilever whose strength varies not as pitch ^{2} × width ÷ length, but as pitch ÷ length, because, with a short and moving crank shaft, very little, if any, strength is gained by making the width of a tooth more than one pitch. Thus a reduction of length to $1\frac{1}{2}$in. would have permitted a reduction of pitch to $3\frac{1}{4}$in., an increase in the number of teeth in both wheels, a shortening of the necessary path of contact, and, if three pitches be considered a sufficient width for the teeth of one engine driving wheel, as I think it is, less concentration of pressure on the corners from the lifting of the shaft.

Some people consider double-helical teeth stronger than straight teeth. This is a delusion. Width for width of wheel face, they are much weaker, because, owing to the lifting and end-long motion of crank shafts, the pressure never acts on both treads at the same time unless provision be made for allowing the pinion shaft to move end ways, and even then the force required to overcome the inertia of the pinion, and its shaft, adds seriously to the pressure on the teeth. There is another cause of destructive vibration, namely, irregularity of pitch and inequality of pitch of wheel and pinion. The first is seldom important in machine-moulded wheels, and can generally be rendered innocuous by chipping and filing. The second, depending upon the contraction of the castings, can only be remedied by gearing the wheels more or less deeply than was intended by the

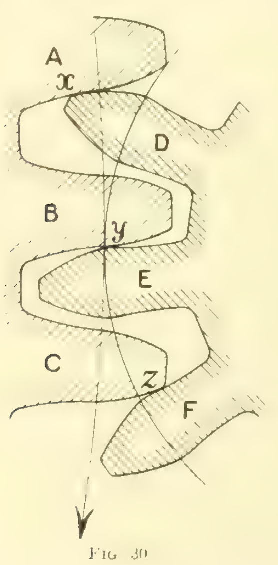


Fig. 30.

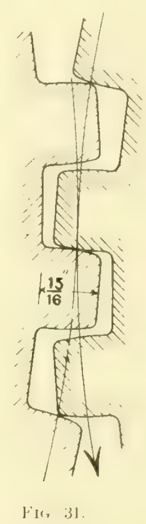


Fig. 31.

designer. In my opinion both wheels of a pair should have pitch circles turned on both sides of the rims, with radii proportional to the number of teeth in each, whether they be the radii marked on the drawing or not. The wheels should be geared to these circles and kept there. The change of the position of the pitch point on the profile will not materially affect the velocity ratio if the teeth be short. The fashionable length of teeth is now 0·45 to 0·55 of the pitch, instead of 0·66 to 0·75 as formerly, and it might be reduced still more with advantage in many cases.

I should like to have said something about the breakages of spur wheels other than breakages of teeth, but as most of the breakdowns of these wheels originate in the teeth, it seemed best to devote the time available exclusively to them. The breakages of spur gearings are now 10 per cent. of the total breakdowns. The reduction in the percentage from 20 to 10 is principally due to the supersession of gearing by ropes. The improvements in design and workmanship have

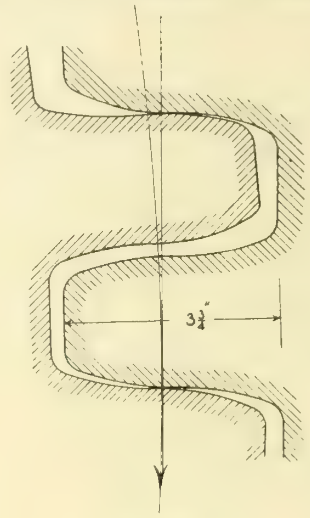


Fig. 32.

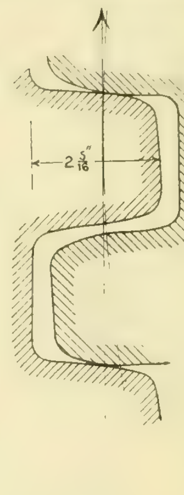


Fig. 33.

done little more than enable wheels to live under conditions which the old wheels could not have faced. But they have done something, and the substitution of steel for iron, of cut or milled for moulded teeth, and of shorter teeth and correspondingly finer pitches, will do a little more, but I doubt if it will ever be possible to transmit more than, say, 1,200 h.p. from the crank shaft of a steam engine by spur gearing.

I have now touched briefly, I could not do more, on the principal breakages of most of the important parts of a steam engine except the beams, gudgeons, and parallel motions and other parts peculiar to beam engines; and as these are becoming obsolete, I have left them out. I will, however, conclude with an anecdote relating to a beam engine. Beams, "walking beams" as they are sometimes called, are usually broken by water in the cylinder or some other extraneous cause, but sometimes they fail gradually from old age, the signs of failure being the appearance of small cracks sometimes in the flanges, sometimes in the webs. A beam in North-east Lancashire began to develop such cracks; they were pointed out to the owner of the engine, their import was explained to him, and he was advised to replace the beam. After listening attentively and in silence to the explanation, he got up, put on his hat, and said: "Mister, them cracks be nowt; I shan't put in no new beam. Why't has nowt to do but wag up and doon."

Mechanical Filtration.—A paper on this subject was read by Mr. Arthur J. Clark at a meeting of the Manchester Association of Engineers on Saturday last. The author first dealt in a general way with the objectionable characteristics of waters from different sources, and then considered methods for their removal. He described a typical installation for dealing with domestic water, and afterwards showed on the screen and gave a brief explanation of the difference in construction of various well-known types of pressure and gravity filters.

The Use of Oil Fuel in the Navy.—In the House of Commons a few days ago, Mr. Churchill stated that the vessels built or building, fitted or to be fitted for burning oil fuel only, number five batle-ships (the "Queen Elizabeth," the "Warspite," "Barham," "Valiant," and "Malaya"), 16 light cruisers, 108 destroyers, and 36 torpedo boats; vessels to be fitted for burning oil and coal—nine battle-ships, 1 battle cruiser, and 2 light cruisers; completed vessels fitted to burn oil and coal—29 battle-ships, 17 battle cruisers, 30 light cruisers, one torpedo-boat destroyer; vessels partially fitted to burn oil and coal—seven.

THE WHITE STAR LINER "BRITANNIC."

THERE was launched from the yard of Messrs. Harland and Wolff, Belfast, on Thursday, last week, the triple-screw steamer "Britannic," of 50,000 tons gross, which they have built for the White Star Line, for service between Southampton, Cherbourg, and New York. The vessel is the largest British liner afloat, and is of similar length to the "Olympic," but has a greater beam. The following are the leading particulars of the new vessel:—

Length overall	About 900ft.
Breadth, extreme	About 94ft.
Depth, moulded	64ft. 3in.
Total height from keel to navigating bridge	104ft. 6in.
Gross tonnage	About 50,000
Load draught	34ft. 7in.
Displacement at load draught	Over 53,000 tons.
I.H.P. of reciprocating engines	32,000
S.H.P. of turbine	18,000
Sea speed	21 knots
Number of decks	9
Passenger accommodation for over	2,579
Crew accommodation	950

The vessel is somewhat smaller than the Hamburg-America liner "Imperator," which has a length of 922ft., a breadth of 96ft., and a gross tonnage of 52,000, with passenger and crew accommodation for 5,000. The "Vaterland," sister ship to the "Imperator," is of slightly larger dimensions, having a gross tonnage of about 56,000.

As a result of their experience with the ill-fated "Titanic," the White Star Line have devoted considerable attention to structural details, with a view to avoiding, as far as possible, a similar disaster. Both in design and workmanship the element of strength has been kept steadily in view, and the most approved structural arrangements suggested by the latest experience have been adopted. The double bottom extending the whole length of the vessel, along with the double skin and water-tight bulkheads, combine to make a structure of exceptional strength and rigidity. The inner skin consists of heavy plating, well stiffened, extending for more than half the length of the vessel, from the water-tight bulkhead in front of the forward boiler-room to the after-end of the turbine engine room. It is strongly connected by longitudinal plates and angles and specially strong connections at the bulkheads and the water-tight divisions. This reinforced structure also extends from the tank top—*i.e.*, from the top of the double bottom—to above the middle deck, and the water-tight bulkheads are carried right up to the bridge deck. The strength and safety afforded by this method of construction will be easily appreciated when it is mentioned that the "Britannic," besides having this extra protection against serious damage, will be able to float with any six compartments flooded.

The propelling machinery comprises a combination of reciprocating engines and a low-pressure turbine, the former driving the two wing shafts and the latter the centre shaft. The two reciprocating engines, each of 16,000 i.h.p., are of the triple-expansion type, having four cylinders, 54in., 84in., 97in., and 97in. diam., by 75in. stroke. They are balanced on the Yarrow-Schlick-Tweedy system, and all the cylinders are fitted with piston valves. The steam, at 200lbs. pressure, after passing through the cylinders of the reciprocating engines, flows into the turbine at a pressure at entrance of about 10lbs. per square inch absolute. The latter is of the Parsons exhaust type, designed to develop 18,000 s.h.p., and is the largest marine turbine yet constructed. Its weight complete is close on 500 tons, and it has an overall length of about 50ft. The exhaust steam from the turbine passes into two condensers. A special valve is, however, provided for passing the exhaust steam from the reciprocating engines direct to the condensers, so that no reversing or astern turbine is necessary on the centre shaft, the astern driving of the ship, and manœuvring in port, being done by the reciprocating engines on the wing shafts. The "change over" from driving ahead with all three propellers to operating the wing shafts, will be effected almost instantaneously. The wing propellers, which are to run at 77 revs. per minute, have three blades, and have a diameter of 23ft. 9in., and the centre propeller four blades and a diameter of 16ft. 6in.

The boilers are of the ordinary marine multitubular type, arranged in six boiler rooms. There are 29 in all, 24 being double-ended, with three furnaces at each end, and five single-ended. The former are 21ft. in length by 15ft. 9in. diam., and the latter of the same diameter but 11ft. 9in. in length. Each of the double-ended boilers has a heating surface of 5,702 sq. ft., and a grate area of 130·8 sq. ft., and each of the single-ended boilers a heating surface of 2,822 sq. ft. and a grate area of 65·4 sq. ft. There are thus 159 furnaces in all, having a total grate area of 3,461 sq. ft. The total heating surface being 150,958 sq. ft., the ratio of grate area to heating surface is 1 to 43·6.

For lighting, heating and auxiliary purposes four 400 kw. steam sets are arranged in two water-tight compartments. The engines are of the three-cylinder compound enclosed type and drive at 325 revs. per minute direct-current compound-wound dynamos of 4,000 amperes, with a pressure of 100 volts, working in parallel. There is also provided, in case of emergency, batteries with a capacity of over 4,000 ampere-hours at a ten-hour rate. An auxiliary power plant comprising two 30 kw. steam-driven sets is located on the saloon deck, situated about 20ft. above the water line, and will be used for charging the accumulators and for providing current when the ship is in port.

The passenger accommodation will be generally of a similar character to that in the "Olympic," the "Britannic," being a larger ship, having greater facilities for the passengers. There will be accommodation for over 2,500 passengers in all, besides a crew of 950. No less than seven of the nine decks are devoted to the passengers, and all classes have been provided for in a way that will ensure both comfort and luxury. The vessel is fitted with the latest and most approved type of electrically-driven boat-lowering gear, by means of which a very large number of boats can, one after the other, be put over the side and lowered to the water line in much less time than was possible under the old system of davits. One of the advantages of the new system is that the passengers take their places in the boats expeditiously and with perfect safety before the boats are lifted from the deck of the vessel, and the gear is so constructed that the fully-laden boats are lowered at a very considerable distance from the side of the ship, thus minimising risk in bad weather. Moreover, the whole of the boats on board can be lowered on whichever side of the vessel happens to be clear. There is a powerful Marconi installation, submarine signalling apparatus, and an electrically driven sounding machine.

THE SLAGGING GAS PRODUCER.*

BY W. H. BLAUVELT.

THE type of gas producer in which the ashes are fluxed and run off as slag was among the very earliest made. Ebelmen built the first one in 1840 at Audincourt, France, only a year after the installation of the first gas producer of which we have record. Charcoal was used as the fuel, with blast-furnace slag and clay as flux. My interest in this type of producer began when as a boy I saw the fluxing producer at Chester, N.J., which was invented by W. J. Taylor, and described by him in 1881. This producer was invented independently by Mr. Taylor to meet the difficulties he experienced in making producer gas for roasting sulphurous iron ores.

It will be of interest to review briefly his description of his producer. It was built like a small blastfurnace, having a hearth 24in. diam. and 24in. high. The bosh angle was 25° from the vertical, the diameter of the bosh 4ft. and at the top 3ft., the total height 12ft. The producer contained one water-cooled tuyere 12in. above the bottom, with a 1½in. nozzle; depth of the coal above the tuyere, 6ft. Mr. Taylor mixed the coal with from 30 to 40 per cent. of basic blast-furnace slag to flux the ash. Occasionally some limestone was also used, but never limestone alone, as the use of the furnace cinder gave a larger volume of slag and made it easier to maintain a proper fluidity. The producer was

* Abstract of paper read before the American Institute of Mining Engineers.

blown with a small Weimer blowing engine, delivering 300ft. of air per minute, at from 1lb. to 1·5lbs. pressure. The slag was tapped every two hours, and was black and glassy in appearance. Broken or egg size anthracite was used. The fine sizes of anthracite could not be made to work. Mr. Taylor expressed the belief that bituminous coal could be used if not too fine, but no experiments were made with this coal. Runs were made of four weeks' duration, with no stops or changes.

Mr. Taylor reported the following advantages: (1) Excellent gas, very uniform in quality. The high fuel bed permitted no air to pass unconsumed, and the gas was almost entirely free from carbonic acid. (2) No cleaning of the producer to remove ashes, so no waste of coal and no cessation or irregularities in the flow of gas. (3) Quantity of gas easily controlled, and "anyone familiar with blastfurnace practice can run it, particularly if cinder for fluxing is available."

The power required for blowing the producer for gasifying 200lbs. of coal per hour was 1·5 h.p., or, assuming 3lbs. of coal per horse-power, 2·25 per cent. of the coal gasified. This consumption of steam compares favourably with ordinary producers, but the rate of gasification, about 16lbs. per square foot per hour, was not remarkable for the size of fuel used. Mr. Taylor did not continue the operation of the fluxing producer, mainly on account of the skilled attention required in its operation. A man "familiar with blastfurnace practice" is often not available for the operation of producers. The high pressure of blast used and the necessity for employing a blowing engine were also among the disadvantages. He did not state why only the larger and more costly sizes of anthracite could be used, but at present comparative prices this would be a serious objection.

There appears to be no further record of experiments with the slagging producer until within the last few years. A battery of "S. F. H." slagging producers was installed at the glass works at Gironcourt in 1907, and this plant is reported to be still in operation, furnishing gas to the glass works. In the report of the operation of this plant there is no reference to the type of flux used, but it is reported that all kinds of fuel are successfully gasified, no matter what the content of ash, the only necessity being that the fuel contains sufficient fixed carbon to develop heat to gasify the carbon and fuse the ash. It is claimed that the heat required to fuse the ash is much less than the equivalent of the carbon lost in the ash of ordinary producers. One coal containing from 20 to 25 per cent. of ash gave a gas containing from 2 to 3 per cent. of CO_2, 28 to 30 per cent. of CO, and 9 to 10 per cent. of H_2 and CH_4.

The most recent work done with the slagging producer is that described by the U.S. Bureau of Mines, Technical Paper, No. 20. This work was done at the Pittsburg Laboratory of the Bureau, with a view to determining the value of this type of producers for utilising low-grade fuels. It does not appear from the report of these tests that the slagging producer gives results essentially superior to other types of producers for gasifying low-grade fuels. The experiments of the coal-testing plant of the Bureau at St. Louis in 1903 and 1904 showed that fuels containing very high percentages of ash could be successfully gasified in producers of the ordinary type.

The report of the Bureau of Mines does not give the dimensions of the producer used, but six air tuyeres were employed and in addition four separate steam tuyeres located above. On account of the extremely high temperatures, it was found necessary to provide pipe coils in the brick lining for water cooling, and magnesite brick was used between the coils and the fire. The cooling coil extended over a space of 20in. above the air tuyeres. The blast pressure used was from 5in. to 16in. of water, and it was found advantageous to pre-heat the air to about 440° Fah. Steam was employed at times up to 0·75lb. per pound of fuel gasified, and it was found that this produced no chilling effect on the slag, as the steam was introduced above the point of highest temperature. It was found difficult to operate this type of producer intermittently without trouble from the chilling of the slag, so it does not appear that it would be satisfactory in cases where gas is required only in the day time, for example. The analysis of the gas showed high CO and low CO_2 content, the latter being as low as 1·5 per cent., but no analyses are reported showing the effect of steam on the composition of the gas.

The experiments developed a number of difficulties in the fluxing of the ash, and it was found that the theoretical percentage of limestone was not nearly sufficient to produce a fluid slag. Frequently large quantities of fine ash blew over with the gas, "because of the heavy air blast," and probably some of the limestone was blown over with it. One occasion is reported where practically all of the ash and limestone escaped in this way. Comparing the air pressures reported with those used in producers of the ordinary type, it would be interesting to observe, in further experimenting, if a careful proportioning of the depth of the fuel bed to the rate of combustion would reduce the trouble from this source. When the conditions were right and the operation of the producer was maintained continuously there was no trouble in tapping off the slag in a satisfactorily fluid condition, and in maintaining a uniformly high quality of gas.

The latest work with the slagging producer is described in a French patent issued to E. Servais, January 21st, 1913. In this producer there are two sets of tuyeres, one set arranged just above the fire zone and supplied with steam or gas to reduce the temperature in the fuel bed by its decomposition. A second set of tuyeres is arranged just below, through which the air blast is admitted. These tuyeres are set in an eccentric ring, in order that a whirling movement may be given to the air in order to agitate the molten slag in the crucible. The inventor claims that this rapidly melts down any solid lumps that may form. A combustion chamber is arranged beneath the crucible in which a mixture of gas and air may be burned to help in maintaining the temperature above the fusing point of the slag. In operating this producer the fuel is sprayed with lime water, or mixed with a suitable amount of basic blastfurnace slag.

The work done thus far with the slagging producer does not indicate that the problem has been thoroughly worked out, and there is much experimenting to be done before this producer can be put on a commercial basis. The increasing cost of the higher grades of fuel, and the large amounts of low-grade fuel that are available in almost all parts of the country, make the perfecting of a producer that will successfully gasify these low grades a most interesting and important problem.

There is one field where the slagging producer would have material advantages. It would be ideal for gasifying coals having a fusible ash. No matter how badly the ash might clinker in an ordinary producer, it would have no terrors for the slagging producer; in fact, the more fusible the ash, the better. Such coals are ordinarily gasified with the use of an excess of steam, which is not only costly to generate, but injurious to the gas, as much of it passes through undecomposed. There are many of these clinkering coals which are objectionable in the ordinary gas producer, and if the slagging gas producer can be worked out so that the cost of operation is about on a par with other types, it will find a field of usefulness waiting for it.

The Junior Institution of Engineers.—This live institution announce the following arrangements for this month: March 6th, at 39, Victoria Street, 8 p.m., Mr. F. E. Rainey, on "Maihak Indicator and Bottcher's Power Counter": March 13th, at 39, Victoria Street, 8 p.m., Mr. F. H. Taylor on "Lightning Conductors and their Tests": March 14th, North-western Section visit oil tank steamer at Mode Wheel, on the Manchester Ship Canal; March 16th, ordinary meeting at 8 p.m. at the Institution of Electrical Engineers, Victoria Embankment, paper on "Some Practical Notes on the Running of Gas Engines and of Gas Producers," by Mr. W. A. Tookey, M.I.Mech.E.; March 20th, at 39, Victoria Street, 8 p.m., Mr. W. H. Sayers on "Aeroplanes as Engineering Structures"; North-western Section meeting at the Municipal School of Technology, Manchester, 7-45 p.m., paper by Mr. W. A. Tookey, M.I.Mech.E., on "Some Practical Notes on the Running of Gas Engines and of Gas Producers"; March 26th, North-western Section at Manchester, 7-45 p.m., Mr. T. R. Wollaston on "Power Driving of Small Workshops": March 27th, at 39, Victoria Street, 8 p.m., Mr. A. Forbes on "Harmonigraph as Applied to Advertising."

ELECTRICAL PYROMETRY.

OF all the methods which enable the engineer or industrial worker to determine high temperatures up to 3,000° Fah., or 1,600° C., electric pyrometry is unquestionably the most simple, the most exact, and the most reliable. The method is applicable to the most varied processes, whilst the instruments can be installed and used by any ordinary workman. The temperature, moreover, can be determined near to or at any distance from the source of heat, or it can be recorded graphically for future reference, and as a check on the attendant at any convenient distance from the source of heat, even at a place inaccessible to the person who is to be checked.

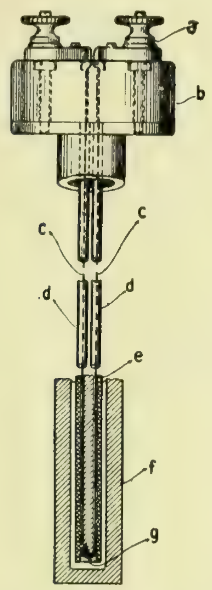


FIG. 1.

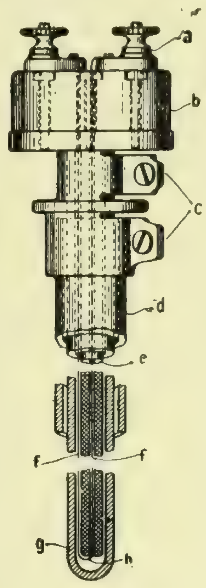


FIG. 2.

Fig. 1 (*a*) terminals; (*b*) head of hard porcelain; (*c*) platinum, platinum-rhodium wires of element; (*e*) fire-proof insulating end-piece of marquardt masse; (*f*) oval Mannesmann steel tube; (*g*) hot junction of wires.

Fig. 2 (*a*) terminals; (*b*) head of hard porcelain; (*c*) reduction clamp to secure renewable steel protection sheath; (*d*) steel sheath; (*e*) insulating tube of marquardt masse; (*f*) platinum, platinum-rhodium wires of element; (*g*) tube of marquardt masse; (*h*) hot junction of wires.

Temperature has been defined as the measure of the tendency for heat to pass from one body to another. In determining temperature, therefore, we observe or record the temperature of the material of which the instrument is made. Owing to the fact that the electromotive force set up in the thermo-couple of an electrical pyrometer varies with the slightest change of temperature, and that these changes are immediately indicated by the galvanometer, we have in the electrical pyrometer a very accurate and reliable instrument for measuring the temperature or heat employed in an industrial operation.

There is one definitive heat at which a substance under treatment will undergo the desired change, or at which the greatest economy of working is obtained, and it is therefore essential for the engineer or manufacturer to determine this point correctly for every operation, and to provide his workers with ready means to ensure that this heat is obtained or maintained as required.

Electrical pyrometers are used in a large number of industries with great success; in fact, many of the intricate modern manufacturing processes could not possibly be carried on without them. Manufacturers are recognising more and more that by exercising a strict scientific control over all operations the output can be increased, whilst at the same time the quality of the goods is much improved or standardised, and the utmost economy is ensured all round.

A complete electrical pyrometer consists of a thermo-couple for exposing to the source of heat, and a sensitive indicating or recording galvanometer, together with the necessary connecting wiring. An electromotive force is set up in the couple when exposed to the heat, and this is measured by the galvanometer. The thermo-couple consists essentially of two wires or rods of different material, which are joined or fused together at their extreme ends where exposed to the heat (hot junction). The other extremes of the rods, called the cold junction, which project into the open air, are connected by means of screws to the leading wires of the galvanometer.

The two rods of the thermo-couple are of different electrical conductivity. If, therefore, the ends of the rods at the hot junction are heated, a difference of potential is produced, causing an electric current to flow, varying in strength with the degree of the thermal difference between the cold and hot junctions, or with the intensity of the heat to which the thermo-couple is exposed.

The relation of this current to the temperature has been determined accurately by experiment, and the scale of the galvanometer can therefore be divided to read directly in degrees Fahrenheit or Centigrade; thus, as soon as the thermo-couple is exposed to heat the electric pressure or current produced in the two rods actuates the mechanism of the galvanometer, and the needle of the latter indicates or records directly the exact temperature of the hot junction, or at the place where the thermo-couple is inserted.

As the electric current produced in the couple through the heating of the hot junction depends on the difference between the temperature at the two extremes of the rods, it is, of course, essential that the outer ends of the rods or the cold junction be kept cool. As this cannot, however, be always obtained in practice, an adjusting screw is provided, as will be explained later, by means of which the finger of the galvanometer can be adjusted accordingly. For very exact measurements, or in cases where, for want of space, very short thermo-couples must be used, the latter are made with water-cooled head. The constituents of the thermo-couple vary according to the intensity of the heat for which they are intended.

Messrs. Schäffer & Budenberg, Ltd., of Manchester, who have for years specialised the manufacture of temperature indicating and recording instruments, have recently placed on the market two new series of electrical pyrometers. The first series for temperatures up to 900° C., or 1,650° Fah., are base metal-couples called the "Pyrodur" couples. These couples develop a very high thermo-electric force and the galvanometers in consequence can be of a very robust and simple construction. The other series comprises platinum, platinum-rhodium couples with wires of 0·5 mm. diam. for temperatures up to 1,100° C., or 2,000° Fah., and platinum, platinum-rhodium couples with wire of 0·55 mm. or 0·6 mm. diam. for still higher temperatures up to 1,600° C., or 3,000° Fah.



FIG. 3.

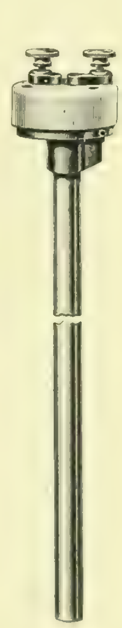


FIG. 4.



FIG. 5.



FIG. 6.

It will be noticed that the latter diameters are much greater than usually employed. Messrs. Schäffer & Budenberg, however, strongly recommend the use of these extra thick wires for the extra high temperatures. Their initial cost is naturally

higher, but, as infinitely greater durability is ensured thereby, the extra outlay is soon repaid. If thinner wires are employed, breakages of the wire often occur owing to expansion stresses in the different materials. Moreover, if the more or less delicate protection tubes which must necessarily be employed for the highest temperatures should accidentally be cracked, the thin wires, the strength of which is naturally much impaired under the high temperatures, are apt to break, allowing the bottom portion of the couple, including a considerable portion of the expansive wires, to fall into the furnace, where it is generally irretrievably lost.

It is very essential that the thermo-couples, whether made of base or precious metals, are suitably protected or armoured. The protection usually consists of an inner insulation and an outer covering (to resist the temperature to which the couple is to be subjected and the effect of oxidising gases or chemicals), and possibly also an additional protection of either steel or some special ceramic product, as a protection against mechanical injury or sudden changes of temperature. Figs. 1 and 2 show the section of two typical constructions.

Figs. 3 to 9 show a number of couples armoured or fitted up for different purposes. In Fig. 3 the stem of the couple is protected by a strong steel tube for use in connection with annealing and hardening furnaces, boiler flues, bakers' ovens, hot blast mains, drying stoves, heating plants, muffle furnaces, and general experimental work, and all purposes where it is desirable to protect the couple against mechanical damage. This is suitable for temperatures up to 1,830° Fah., or 1,000° C. Fig. 4 shows a similar couple protected by a thin light-steel tube. This is specially sensitive, and intended particularly for occasional tests.

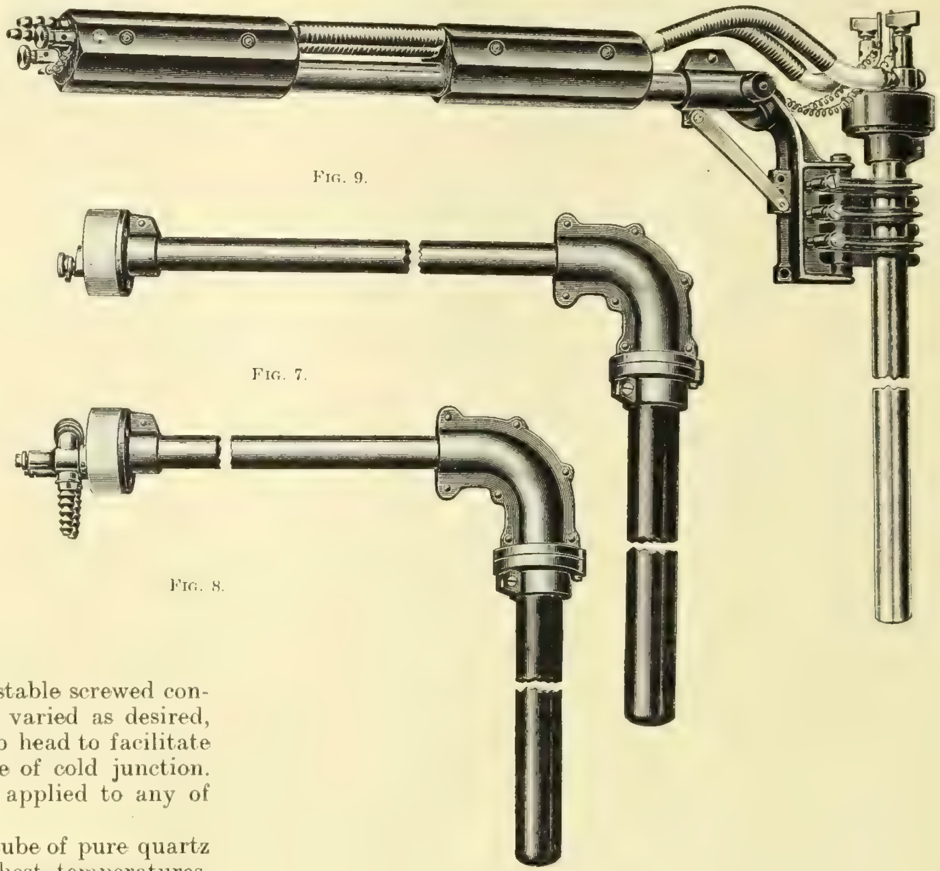


Fig. 9.

Fig. 7.

Fig. 8.

Fig. 5 shows a thermo-couple with adjustable screwed connection, allowing length of insertion to be varied as desired, and a small mercurial thermometer fitted to head to facilitate setting pointer of indicator to temperature of cold junction. These two attachments can, of course, be applied to any of the different couples.

Fig. 6 shows a couple armoured with a tube of pure quartz or marquardt masse, intended for the highest temperatures, and an additional guard of steel tubing from which the quartz or marquardt masse projects at the end. Tubes (made of quartz or fused silica) are gas-tight and are not affected by sudden and great changes of temperature. They are also safe against chemical action, as quartz is unaffected by acids, with the exception of phosphoric acid at high temperatures and hydrofluoric acid. Hydrochloric, sulphuric, or nitric acid, or mixtures of acid, such as aqua regis, have absolutely no action on quartz. Quartz tubes are largely favoured on account of these features. Being of fragile nature, however, they must naturally be protected against mechanical injury. If exposed frequently or permanently to temperatures above 2,010° Fah., they deteriorate and must be renewed frequently.

Fig. 7 shows an angular thermo-couple with Mannesmann steel-tube protection, with quartz insertion and renewable steel protection sheath of $1\frac{1}{4}$in. outer diameter, which is especially designed for metal and salt hardening baths and other purposes, where the couple is inserted in open vessels, the head or cold junction being thereby kept away from the rising heat. Fig. 8 shows an angular couple with water-cooled head, whilst Fig. 9 shows a special folding handle for converting an ordinary couple into an angular couple. Fig. 9 shows the couple with water-cooling to the head. It is, however, very often made without it.

For very exact measurements, or where special circumstances necessitate the employment of a very short couple, or where a straight couple is to be used occasionally, over an open metal or chemical bath (held in a handle as Fig. 9), it is advisable to provide the head of the thermo-couple fitting with water cooling, so that the terminals or "cold junction" can always be kept at a steady temperature.

The indicator is essentially a sensitive galvanometer with the scale direct-reading in degrees Fahrenheit or Centigrade. The latter has been made possible, as the electromotive force produced in the couple is in a definitive ratio to the temperature of the hot junction.

(To be continued.)

INSTITUTE OF MARINE ENGINEERS.

The 25th annual meeting of the Institute of Marine Engineers was held in London on Thursday, February 26th, Mr. Thomas L. Devitt presiding. The annual report showed that the membership of the Institute at the close of the financial year stood at 1,408, a net increase of 58 during the session. The total sum to the credit of the City Premises Fund amounted to £8,193. 5s. 8d. The foundation stone of the building was laid on October 29th, 1913, by the Lord Mayor of London (Sir David Burnett, Bart.), and considerable progress had been made with the work. The "Titanic" Engineering Staff Memorial Fund had realised the sum of £2,940. Of this amount £300 had been handed over to the Southampton Memorial Committee for the erection of a memorial at that port. An agreement with the Royal Merchant Seamen's Orphanage had been made, under which the Institute would have the nomination of one eligible child each year, and the Institute would also be represented on the Board of Management of the Orphanage. Other items of the Institute's work were dealt with under the headings of papers and discussions, transactions, visits to works, Lloyd's Register Scholarship, essay awards, Denny gold medal, experimental department, junior section, library and reading-room, Board of Trade Advisory Committee, Royal Naval Reserve, &c. The obituary list included the names of two past presidents, the late Sir William White, K.C.B., and the late Sir David Gill, K.C.B.

In submitting the revenue account and balance-sheet, the hon. treasurer stated that the total income from all sources during the year was £1,430. There was a credit balance of £339, and after adding entrance fees, a total of £451. 12s. 5d. was added to the revenue account during the year, that account now standing at £4,279. The amount spent on papers and discussions was £497.

The reports were adopted on the proposal of Mr. H. A. Ruck-Keene, seconded by Mr. A. E. Battle, who, together with the Chairman, congratulated the members on the excellent position of the Institute, and on the work accomplished

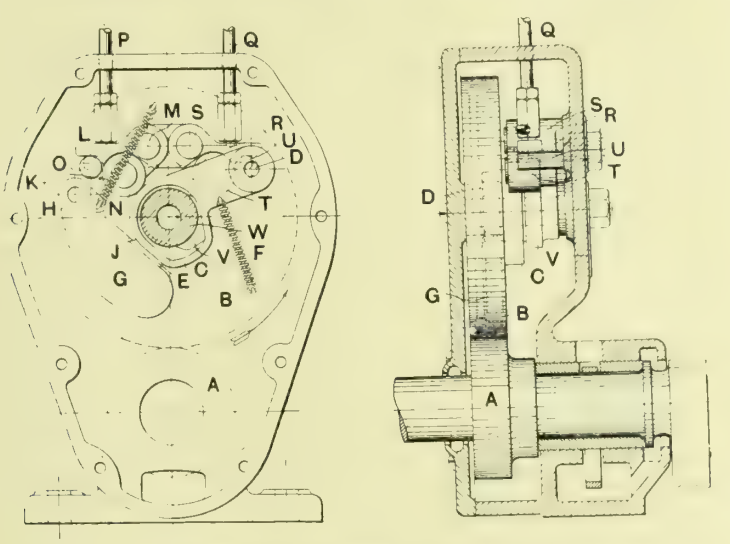
during the year. A vote of thanks to the retiring president (Mr. Devitt) was proposed by Mr. A. Boyle and seconded by Mr. Geo. Adams.

The scrutineers (Messrs. P. Smith and C. Hudson) reported that, as a result of the ballot, the following office-bearers and members of council were elected for session 1914-15: President: Sir Archibald Denny, Bart., LL.D.; hon. treasurer: Mr. Alexander H. Mather; hon. secretary: Mr. James Adamson; members of council: Messrs. A. E. Battle, P. T. Campbell, B. P. Fielden, H. A. Ruck-Keene, and W. T. Seaton. Mr. W. E. Archer was reappointed hon. solicitor and Messrs. J. Clark and A. Robertson as hon auditors.

The meeting concluded with a vote of thanks to the chairman, on the proposal of Mr. R. Leslie, R.N.R., seconded by Mr. W. T. Seaton.

GOVERNING MECHANISM FOR OIL ENGINES.

THE accompanying illustrations show an arrangement for governing the speed of oil engines and maintaining a more even temperature in the vaporiser on all loads, the joint invention of Messrs. E. C. Blackstone and F. & E. Carter, Rutland Engineering Works, Stamford. There is fixed on the engine crank shaft the spur pinion A which drives the governor disc B at half the crank-shaft speed. On this disc is pivoted at D the swinging cam C, which has fixed to it the ledger plate E, adapted to engage with the ledger J on the governor weight G, which is pivoted to the disc B at H. The governor weight resistance spring is indicated at K. The swinging cam C operates both the inlet and exhaust valves, the inlet valve or valves through the roller N, lever L, pivoted at M, and the push rod P, and the exhaust valve through the roller T, lever R, pivoted at S, and the push rod Q. Eccentric adjustable stops O U are provided for the valve levers L and R. The swinging cam C opens and closes the exhaust valve at the usual times, but another auxiliary exhaust cam V of shorter phase is formed integral with the disc B, this cam being fixed a shade in advance of the swinging cam, so as to take the work of starting the exhaust valve



GOVERNING MECHANISM FOR OIL ENGINES

from rest. The roller T is of double width to engage both the fixed and swinging cams, but the roller N is a narrow roller and engages the swinging cam only. During governing periods the weight G flies outwards, and the swinging cam being no longer supported fails to open the valves, but is pressed down by the valve rollers T and N on to the sleeve W against the spring F, which returns it to its normal position after the raised portion of the cam has passed the rollers. The swinging cam being inoperative, the exhaust valve is actuated by the fixed cam V, which does not lift the exhaust valve so much as the swinging cam and closes it about half-way of the exhaust stroke, causing a portion of the exhaust gases to be compressed, thus retaining the heat of the combustion chamber and vaporiser during governing periods.

THE USE OF STONE DUST FOR PREVENTING COLLIERY EXPLOSIONS.

AT a meeting of the Midland Institute of Mining Engineers recently held at Doncaster, Mr. Robert Clive read a paper on "Stone dusting at Bentley," which was a report presented to the Doncaster Coal owners (Gob Fires) Committee. The author said the value of incombustible dust as a means of retarding, if not preventing, coal-dust explosions was now universally admitted by all mining engineers who had studied the subject. Experiments made by the Eskmeals Committee conclusively proved that incombustible dust did not render a mixture of firedamp and air more inflammable, but, on the contrary, owing to the heat absorbing properties of the material used, the mixture was slightly less inflammable. The Altofts experiments, made on a practical scale, showed that a mixture of stone-dust and coal-dust in the proportion of 1 to 1 was not explosive. The same result had been confirmed by the Eskmeals experiments. At Bentley the pure coal contained from 3 to 3½ per cent. of ash, and the incombustible dust used for stone-dusting about 88 per cent. of ash. A mixture yielding 50 per cent. of ash would therefore contain about 54·8 per cent. of stone-dust and 45·2 per cent. of coal-dust. The 12 per cent. of volatile matter in the stone-dust consisted mostly of moisture, partly of carbon dioxide, with a slight percentage of inflammable material.

Under the present existing conditions at this colliery it might be said to be a practical proposition to keep the main haulage-roads, travelling-roads, returns, and crossgates in a thoroughly safe condition, with the average percentage of ash in the fine dust from several samples between 50 and 60 per cent., or something like in the proportion of just over 1 of stone-dust to 1 of coal-dust. To get and keep a much higher percentage of stone-dust than this would, the author thought, be impracticable, owing to the very large quantity that would have to be constantly applied. He did not think it practicable or necessary to stone-dust the crossgates immediately contiguous to the face, the ordinary gates, or the face, as the quantity of dust was small, the dust was coarse, and it contained well over 37 per cent. of ash. It was also impracticable, owing to the fact that the face roads were turned over twice or three times a week, and it would be necessary to stone-dust the face every turnover.

The proportion of 10 of stone-dust to 1 of coal-dust had been frequently mentioned as a practical proportion by mining engineers, as well as by some Inspectors of Mines. In the writer's opinion, it was absolutely impossible to keep any roadway up to this standard, and it was quite unnecessary to do so. At Bentley the natural dust deposited in all the roadways, and in the face itself, was exceedingly high in ash (from 28 to 55 per cent.). In this case therefore a smaller quantity of stone-dust was necessary to produce a safe percentage of ash than would be the case in mines which produced a more dangerous dust. Mr. Clive gave the following particulars of the actual effect of ash on recent explosions:—

Courrières Explosion, March, 1906.—An analysis of samples demonstrated that the flame traversed the roads where the dust contained up to 28 per cent. and less of ash, and in one case there was only 8·8 per cent. of ash. They also showed that the explosion stopped where the dust contained 42·3 to 59·9 per cent. of ash.

Talk-o'-th'-Hill Explosion, May, 1901. The flame traversed the roads where the dust contained up to 31·5 per cent. of ash. The explosion stopped where the dust contained 44 per cent. and possibly 39 per cent of ash.

Cadeby Explosion, July, 1912.—It is difficult to draw any conclusions from the data given in the report on this explosion, but the author understands that in all cases the explosion ceased where the dust contained 36 per cent. or more of ash.

New Light Armoured Cruisers. The light cruiser "Cordelia" was successfully launched from Pembroke Dockyard on the 23rd ult. She is the third of the class to be launched, the other two being the "Arethusa" at Chatham and the "Aurora" at Devonport. The light cruiser "Cleopatra" was laid down at Devonport Dockyard on the 25th ult.

AIR FILTRATION, WITH SPECIAL REFERENCE TO THE VENTILATION OF ELECTRICAL MACHINES.*

BY WILLIAM ERNEST GURRY, STUD.INST.C.E.

THIS subject has been chosen, first because air filtration has long been essential to many industries, and has been recognised as an almost necessary improvement to as many others, and secondly because it has a most important bearing on the mechanical production of power. As applied generally to a wide range of industries, some methods of air filtration may be described here. Where light and dusty products of comparatively high value are dried by circulation of hot air it is often advantageous to collect the material which has been mechanically carried away by the air. To accomplish this the most crude form of apparatus is necessary, and usually consists of a chamber (of sufficient cross-section to enable the gas to pass through at a low velocity) having a series of cloths stretched across it. A modified form of this apparatus has been used for separating dust from blastfurnace gases. This consists of bands of textile material circulating across the casing or flue at right angles to the direction of the flow of gases and passing outside through gas-tight slots into a chamber fitted with vacuum dust extractors, which continuously remove the filtered dust from the bands.

An electrical method for the deposition of suspended particles in air is also of some interest, particularly in cases where pure dry air is required in comparatively small quantities. The current used for this purpose is one of high tension, and its action induces the agglomeration of suspended particles into aggregates sufficient in size to settle under the influence of gravity. The current is produced by transforming alternating current up to 20,000 to 30,000 volts, and then commutating this high potential current into intermittent direct current by means of a special rotary contact-maker driven by a synchronous motor. This process was first used for the deposition of acid mist in a works producing sulphuric acid by the Mannheim contact process. It has also been used in a modified form, and with suitably constructed apparatus, for the removal of suspended matter from gases evolved in lead and copper smelting works and the gases from Portland-cement kilns.

Perhaps the most interesting of all applications of air filtration is its adaptation to the system for ventilating electrical machines for the production of power; this being one of the most interesting problems in engineering. It is more than ever interesting to-day on account of the active competition existing between the various systems for its production. This competition is made even more keen when we realise that there are a host of engineers and inventors striving towards lower consumption of power by the various machines to which electricity has been applied. The station engineer, finding the demand for power thus decreasing, has to turn his attention to its more economical production.

The brilliant invention and application of steam as a practical motive power by James Watt, long and most useful as its career has been, cannot be looked upon as the ultimate solution of the power problem even for large powers. Immense improvements can, however, be made, and it is quite probable that it will still have an enormous application, since there is at present no other system which will completely fill the same requirements. With a high temperature steam turbine of large size generating electricity to supply power for all purposes on land, one has the advantage of a machine of high efficiency which is not limited to oil for its fuel. After all, the great problem of the country is so to utilise the coal produced that it may fulfil our every requirement. It is probable that as improvements are made the whole of the coal used for firing will be gasified and the by-products recovered. This done, we shall not only have an ample and cheap supply of fertiliser for the land, but also a great quantity of tar and oils which will form a suitable means of firing for naval purposes, and obviate the necessity of purchasing fuel oil from abroad and the risk and cost it involves. We shall also have a fair supply of benzol for small motor requirements. This gives a fairly practical solution of the fuel problem, and when we consider that the electric motor giving its power in a rotary form supplied from large stations is fast displacing all forms of steam engine, we may fairly safely assume that the solution of the power problem is to be found by applying large steam-driven turbines to electrical generators, and working along these lines, any increase in economy is only to be obtained by refinements to be made in and in connection with existing machinery.

A great difficulty in connection with turbo-driven generators for years past has been the "heating up" of the electrical windings and the consequent danger to the insulations; it might be almost said that the temperature rise which the machines will stand is the only condition governing their output. This difficulty was at first overcome by running the machines with open ends and natural ventilation, but the rise in temperature at even less than full load was often excessive. It was then found that by fitting end bells, air ducts, and forced ventilation, the manufacturers, without materially altering the design, were, with the same size of machine, able to nearly double the output with diminished rise in temperature, and at the same time to proportionately reduce the selling price per kilowatt of rating. Although this proved a great asset to purchasers, and the advantages of the system were manifest, there were still minor difficulties to be contended with, chief among which were the filtration and conditioning of the air before passing it into the machine. This was at first accomplished by using cloth screens of rather a crude nature.

The air required to effectively cool a 5,000 kw. set is approximately 30,000 cub. ft. per minute, or about 6 cub. ft. per minute per kilowatt, and is usually drawn from outside the building, or, under some conditions, from the engine-room basement. Wherever possible, it is far preferable to place the filter outside the building. In cases where this apparatus is placed inside the building, the air duct between the filter and the generator is necessarily short, and often, owing to the sharp corners that have to be encountered, "channelling" of the air occurs, with the result that the eliminator-plates are hampered in their work and the air passing through is not relieved of all its moisture. A case in point is one in which, owing to the filter being placed directly under the generator, a sharp corner occurred in the duct, and the air on the inner corner had a velocity 25 per cent. less than that on the outer. The result was that the air going directly round the corner retained some of its free moisture, which passed directly upward into the machine. This state of affairs would not have occurred if the filter had been placed outside the building, when the ducts would have been longer and contained easy bends. Further, air drawn from outside the building is usually lower in temperature than that in the engine-room basement and will therefore have a greater cooling effect on the generator.

The question of oil-vapour in the atmosphere is also of importance in deciding the best point from which to draw air for cooling purposes, particularly so in cases where no filters are used. In most districts in this country there is a prevalent wind; this is very marked on the North-east Coast, where the winds blow in a comparatively constant direction for nine months in the year. In these cases air should be drawn from outside the building on the leeward side. Any dust drawn into the machine will settle to a certain thickness, but beyond this, being dry, it will be drawn off. If, however, there is any oil-vapour in the air, this dust will keep on piling up until the machine becomes quite choked up. Further, in the case of using cloth filters, the presence of oil-vapour makes the cleaning of cloths far more difficult. In some cases it is possible, where only ordinary dusty air is being filtered, to clean these cloths by means of vacuum cleaners; but where oil-vapours are present the only way to accomplish the same end is to remove the cloths and boil the dirt out of them.

Circulation of air is accomplished by means of separate electrically-driven fans, or by fans built in the machine on the rotating parts. This arrangement is particularly favourable to comparatively small units, say, 3,000 kw. to 5,000 kw., being cheaper, more efficient, and reliable. Where, however, units of high power are running it is preferable to provide a main air duct common to all the machines, having a branch and damper to each, and to have fans on the motors themselves, supplemented by motor-driven fans for use under excessive overload conditions, the air filters being fitted at

* Paper read before the Students' section of the Institution of Civil Engineers, December 19th, 1913

the end of the intake duct in a suitable house outside the building.

Air in the surroundings of a power-house is always charged with fine particles of dust in suspension, this being particularly so in manufacturing and coal-mining districts. Unless every care is taken to remove this dust, the windings of the machine become caked and the air ducts choked, and with the consequent rise in temperature there must necessarily be a corresponding decrease in efficiency. The state of affairs in this direction may be seen at a glance by using a sensitive air gauge, which, fitted to the air duct, becomes a most usefui accessory. In cases where the precaution of removing dust from the air is not taken, there can be little doubt that the heat and constant action of the dust and grit impinging at high velocity on the windings must seriously affect their insulation. In fact, the action is so detrimental as to make the surface of the windings porous. The insulation of a machine in this condition, allowed to cool down in a humid atmosphere, will rapidly fall to far below a safe figure owing to absorption of moisture. To this cause may be attributed many more or less mysterious "burn-outs." This unpleasant experience is by no means rare, and usually occurs when a machine is again brought into duty after a lengthy rest.

The type of air-conditioning apparatus most generally in use consists of a closely-woven cloth stretched on a suitable framework and arranged so as to present a large surface to the incoming air in order to keep the pressure and velocity at this point as low as possible. Allowing one-fifth of a square foot of filter-cloth per cubic foot of air per minute, we have an extremely low velocity and consequently no appreciable pressure on the cloth. In the previously mentioned example, 30,000 cub. ft. of air per minute were required to effectively cool a generator of 5,000 kw.; allowing a velocity at 5ft. per minute, we find that the filter-cloth surface required is 6,000 sq. ft. Naturally this will not be arranged in one surface, the usual method being to arrange the surfaces in a number of cylindrical forms grouped together vertically or horizontally. However, under the most favourable conditions, such filters can only be regarded as partially filling a most needed want, and possess many disadvantages, among the foremost being: (1) Relatively large space necessary for accommodation. (2) Frequency of cleaning to keep them in running order. At Deptford in a heavy fog it was necessary to clean the filter-cloths every 48 hours. (3) Short life of filter-cloth. (4) Annual expense in filter-cloths, which are costly to renew, and which may on moderate-sized units cost as much as 0·66s. per kilowatt per annum. (5) Length of time necessary to clean the filter, which is a dirty job, and can hardly be carried out without taking the machine out of commission for a considerable time. (6) Risk of fire owing to the combustible nature of the filter-cloth. (7) Frequency of choking up unless a liberal area is provided, which with consequent rise in air pressure often causes the cloths to burst.

It should be noted that the air pressure on the intake duct should never be allowed to rise above 1in. to 1¼in. water gauge. Above this there is a likelihood of oil-vapour being drawn in from the bearings, if the oil is run at an excessively high temperature, which often occurs with turbine installations and which is most harmful to the insulation. These troubles have sometimes become so arduous that filter-cloths have been cut out altogether, the machine running better without them. A moderately efficient substitute was found in using screens of Kaiar matting, kept continually wetted by water trickling over its surface from a perforated pipe above; the matting being cleansed by periodically flushing it with water and occasionally also thoroughly cleansing with a hose.

This finally led to the adoption of a principle, a modified form of which has long been used where the Plenum system has been adopted for the ventilation of public buildings. This is the use of a water-spray. To draw air which has been previously passed through water into the internal parts of a high-tension generator seems at first sight to be rather a risky proposition, but experiments made in connection with such an equipment for ordinary ventilation purposes were made in London and proved highly successful. The machine consists of a strong rectangular galvanised sheet-steel chamber, one end of which is open and serves as the air intake. This opening is of sufficient size to ensure the velocity of the air at this point being fairly low when the machine is running at top speed, and is fitted with louvres which evenly distribute the incoming air on to the water screens fitted some 2ft. or so inside. This is made up of a number of small nozzles spaced about 6in. apart uniformly over the entire area. Beyond this screen an eliminator is placed, and air passing through is relieved of its moisture by contact with its plates, which are very similar to those placed in an ordinary oil separator, such as is fitted in many engine exhaust pipes, and so directly into the generator. The base of the chamber forms a fresh-water tank, and has a ball cock on the supply pipe to keep a constant level and make up for any loss by evaporation. A small centrifugal pump circulates this water at a pressure of about 20lbs. to 25lbs. per square inch through the system. The nozzles project the water, in the form of an atomised spray, directly against the incoming air. This space, when the apparatus is working, has the appearance of a dense bank of cloud, and all solid matter in suspension in the incoming air is caught and precipitated in the tank. Any moisture or grit mechanically carried beyond this is effectively trapped by the eliminator, and nothing but the remaining and now cool humid air passes on into the machine.

The advantages of this type of filter are: (1) Comparatively small space required for accommodation. (2) Rapidity and ease with which the apparatus may be cleaned, it being only necessary to shut down the pump and drain off the water at intervals dependent on the amount of suspended matter in the air, wash out the tank with a hosepipe, fill and start the pump again. All this can be accomplished in a very short time without even taking the machine off load. (3) The life of the apparatus is practically unlimited. (4) There are no costly filter-cloths to rinse and clean, and the running expenses are more than balanced by (*a*) increased output of the system, (*b*) decreased load on fan, as the water gauge is constant. (5) There is no fire risk. (6) Resistance to air has proved to be less than one-third that due to filter-cloths, and is constant. Thus the power for driving the main fan is proportionately less, whilst the total energy consumed by the whole outfit, including an allowance for the water-circulating pump, shows a substantial saving over that required for driving the cloth filter. (7) After passing through the water-screen filter the air is not only pure but is several degrees colder than the surrounding air, due to its being reduced to wet-bulb temperature. The effect of this air volume for volume is therefore proportionately greater and is most marked during the hot summer months, when an extra cooling effect is of the greatest benefit.

In climates where extremes of heat and cold are experienced it is advisable, in order to avoid freezing of the water, to fit a steam coil in the bottom of the tank and to guard against surrounding air of extremely high temperature by inserting a small refrigerating plant in the water-circulating system, to further cool and control the temperature of the air down to a degree below the corresponding wet-bulb temperature. By this means it is possible to reduce the air temperature to within a few degrees of the temperature of the water through which it is passed.

The cost of the water-screen filter naturally varies with the size of the generator to which it is fixed, and in moderate-sized machines is higher by about 60 per cent. On large machines the advantage is with the water-screen type of filter. A fair comparison between them cannot, however, be made from initial cost, as often by installing such a plant it is possible, by so being able to maintain a high overload on a generator, to save the cost of a new installation, due to increased cooling effect obtained, especially in hot weather. An extra 10 to 15 per cent. overload can be carried on any machine so equipped without increasing the final temperature, and if refrigeration is introduced into the circulating system and the air consequently further reduced in temperature, this overload capacity may be still further increased to 25 or 30 per cent. This being the case, it would not be without precedent to foreshadow that in the near future turbines to drive electro-generators will be of ample size to cope with the extra heavy overloads to which they may be subjected. The only condition then governing their output will be a predetermined safe limit temperature, and the indication of safety by volt and ampere meters will be replaced by electrically-controlled thermometers. The additional output obtainable for the same capital outlay by the extra

cooling effect of this system is perhaps its chief advantage, and amply justifies its general adoption.

One of the first machines to which this system was fitted was one in service in the South of England, generating three-phase alternating current, 50 periods, at 3,000 volts, with 250 volts excitation on the field windings. After running for more than a year with entire satisfaction, the insulation resistance has been consistently maintained, showing that any moisture carried through has harmlessly evaporated on the warm windings of the machine, and that this type of filter can be used with safety for ventilating high-tension machines, or air-cooled transformers, without detriment to their insulation. Humidity of the air may even be said to be beneficial, preventing the insulation from becoming baked hard to destruction, which is too often the case with machines run at a high temperature, and on heavy overloads with dry air circulating through them.

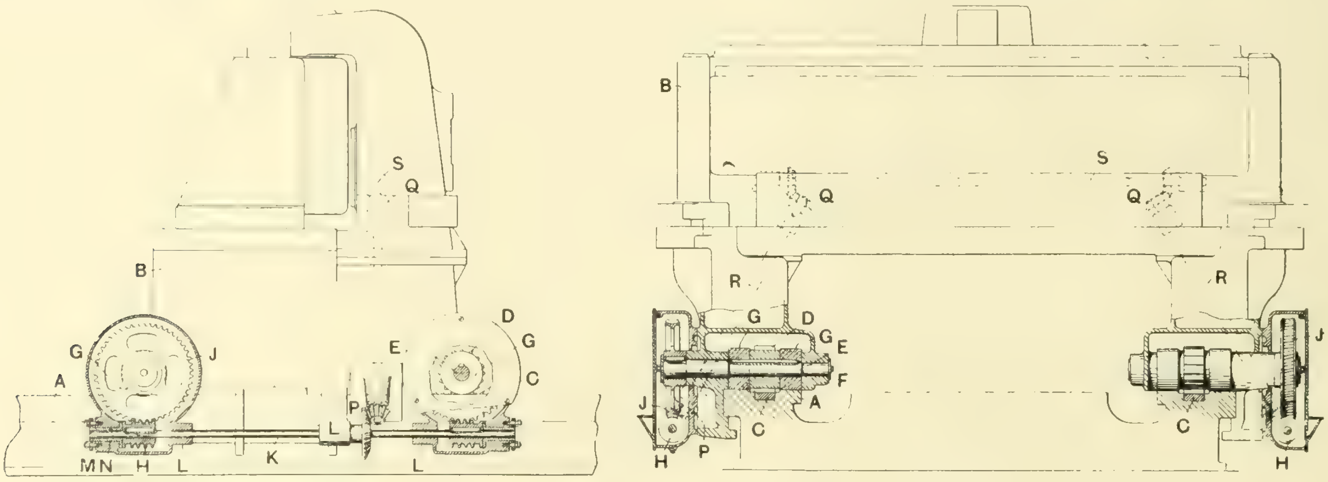
A great point about the application of the water-screen filter to the ventilation of electric generators is that it has led to some most useful discoveries, and added considerably to our knowledge of the actual conditions under which generators were working. The station engineer has been able to discover many of the causes of the not-infrequent "breakdowns," and the dynamo builder has, on the other hand, now been able to modify his design to remedy these conditions.

The results of a test taken recently on a large generator led to some rather interesting changes being made. It was decided to test the effect of moisture from a wet-air filter on the insulation. After running for 18 hours the insulation was found to have dropped from 16 megohms to 3 megohms. The machine was then allowed to stand for some time, and after two hours the insulation resistance had risen to 14 megohms. On the face of it, such a change is most extraordinary, it being common knowledge among engineers that the drying of high-powered electrical generators is a long and expensive job. On running without the filter and making similar tests the drop in the insulation resistance was found to be even more marked. A rather curious explanation is that the day was a foggy one. The drop in insulation resistance was found to be due to settlement of moisture on the neutral earth-wire which was in the air duct between the filter and generator. On standing, this moisture evaporated and a rise in the resistance resulted. The drop was most marked when running without the filter, because the unfiltered air contained most free moisture, which settled on the neutral earth-wire.

The humidity of the air surrounding installations of cooling towers often reaches a figure as high as 90 to 100 per cent. This air, drawn through ordinary cloth filters, represents the same condition as regards risk, if any, to the insulation due to humidity, but without the cooling and cleansing effects of the water-screen. Such results go to show that, contrary to being opposed to the water-screen filter for generator ventilating, engineers should rather welcome it, since the risk to the insulation, if any, has been lessened. The danger of flashing across the terminals, when these are coated with moisture, has disappeared with their removal from the air duct, and thus we may say that the introduction of the water screen has also led to greater safety and reliability. Units of plant of 10,000 kw. and upwards are now by no means uncommon and are being installed by many large undertakings throughout the country, and this system of filtering and conditioning air seems to be, as far as present knowledge goes, the most satisfactory solution of a somewhat difficult problem.

LIEBERT'S SLOTTING MACHINE.

In practice it has been found that in the heavy types of slotting, shaping, and planing machines with rack and pinion feed the movable tool head or work table, when suddenly fed in a very short period of time, moves with great resistance, and thus the tool is fed irregularly. With a view to overcome this objection, Mr. Henry Liebert, of South Drive, St. Annes-on-the-Sea, has patented the arrangement illustrated, Fig. 1 being a side elevation partly in section, and Fig. 2 a cross-sectional view of a slotting machine with rack and pinion feed and movable tool head. A is the tool bed, B the tool head, C the racks on the machine bed, D the feed pinions in gear with the racks, E the axles on which the pinions are secured, and F the bearings on the tool head in which the axles are mounted. An anti-friction roller G is arranged at each side of the feed pinion D, rigidly secured to the axle E. The anti-friction rollers run upon the machine bed A on each side of the racks C, and are held laterally in position together with the pinion D by the axle bearings F. The axles E are connected together at each side of the tool head B by means of worm and worm-wheel gearing H J, the worm wheel J being secured to the outer end of each of the axles E and the worms H upon a common shaft K mounted in bearings L, M in the tool head B. The worms H are rendered longitudinally adjustable towards each other on the shaft K to permit of adjusting the feed pinions D relative to the teeth of the racks C, and thereby obviate backlash between the feed pinions and the racks. The adjustment is obtained by furnishing each end of the shaft K with a sleeve N mounted in the shaft bearings M, one end of the bush bearing against the adjacent end of the worms H, while the other end has a flange through which pass bolts screwed into the bearings M which permit of longitudinally adjusting the sleeves N and thus the worms H. By connecting together the feed pinions D on each end of the tool head B, as described, they become interlocked with the racks C, and the tool head is thus prevented from vibrating or being pushed back. Each of the work shafts K is geared up by means of bevel-wheel gearing P, Q and shaft R and S, with a suitable feed motion, so as to rotate in unison with each other.



FIGS. 1 AND 2.—SLOTTING MACHINE, WITH RACK AND PINION FEED AND MOVABLE TOOL HEAD.

Disastrous Boiler Explosion near Berlin.—A terrible boiler explosion occurred on Thursday, the 26th ult., at an aniline dyeworks at Rummelsburg, East Berlin, at least ten persons being killed and 50 others injured. The factory buildings were reduced to heaps of ruins, which afterwards caught fire and made the work of rescue very difficult.

OIL FUELS AND THEIR APPLICATION TO THE GENERATION OF POWER.*

BY PROF. THOMAS GRAY, D.SC., AND PROF. A. L. MELLANBY, D.SC.

(*Concluded from page 200.*)

Petroleum.—Crude petroleums vary greatly in character; some varieties are pale coloured, mobile liquids, while others are black and highly viscous. The specific gravity ranges from 0·7 to 1·06, and, even in the same field, the gravity of the oil is subject to considerable variation. These extreme values, however, are comparatively rare, the bulk of the oil having a specific gravity between 0·8 and 0·95. The flash point of crude petroleum varies from below 0° Fah. to temperatures above 300° Fah.

Some of the lighter oils begin to boil at temperatures considerably below the boiling point of water, and give off a large proportion of their total volume below 150° C., the bulk distilling over before the temperature reaches 300° C. Oils of this type are distilled for the production of petroleum spirit, illuminating and lubricating oils, and are termed "refinery oils," to distinguish them from the heavier "fuel oils," from which only a relatively small proportion distils over below 300° C. The following results of the distillation of a few samples of petroleum, chosen from a large number of tests made by Redwood,† will serve to indicate the variable composition of the crude oil:—

Source.	Specific gravity	Percentage of Spirit. Up to 150° C.	Lamp oils. 150°—300° C.	Gas oil, lubricating oils, and solid hydro-carbons. Above 300° C.	Coke. Residue.
Sumatra	0·771	37·2	52·0	5·9	0·5
Pennsylvania, Bradford.	0·810	20·0	50·0	25·3	1·1
Mexico	0·970	—	—	88·5	6·5

The gross calorific value of petroleum ranges from 17,000 to 20,000 B.Th.U's. per pound, only falling outside these limits in exceptional cases, and more usually varies from 18,000 to 19,000. Generally speaking, the lighter oils have the higher calorific value. The net calorific value is from 1,100 to 1,200 B.Th.U's. less, the difference depending on the proportion of hydrogen in the oil.

Petroleum is composed principally of hydrocarbons, but it contains also small proportions of oxygen, nitrogen, and sulphur compounds. The ordinary limits of variation are: Carbon from 83 to 87, and hydrogen from 11 to 14 per cent. The proportion of sulphur is, in some instances, less than 0·1 per cent. (Pennsylvania), it is usually less than 1 per cent., but sometimes exceeds 2 per cent. (Texas), and occasionally may reach 4 per cent. or more (Mexico).

The use of crude petroleum as fuel has made rapid progress during the last few years. In the United States of America, which produce more than 60 per cent. of the total output of petroleum, over one-third of the crude oil produced is burned as fuel. The total consumption for power purposes in 1912 amounted to 85 million barrels,‡ of which about 33½ millions were used on the railroads. During 1911 the United States Navy used 15 million gallons of fuel oil; in 1912, 21 million gallons; and for 1913 the consumption is estimated at about 30 million American gallons. The bulk of the fuel oil is burned under steam boilers, a considerable proportion is used for furnace work, and a relatively small quantity is consumed in internal-combustion engines. It is improbable, however, that the present relatively wasteful method of generating power from petroleum by burning it under steam boilers will continue to make progress. During 1912 a reversion to the use of coal took place on a few of the railroads of the United States, and this change is expected to be more evident during 1913, as a result of the increased prices of oil. The future extension of the use of oil to districts more remote from the oilfields can only be expected as a result of the further development of the internal combustion engine.

Recent experiments have shown that many crude oils may be used successfully in the Diesel engine, if free from mechanical impurities. The lighter varieties of crude petroleum, which consist largely of paraffins, ignite easily and burn completely. The heavier varieties, on the other hand, particularly such as contain considerable quantities of asphalte, ignite with difficulty, give a smoky exhaust, and leave pitchy or resinous deposits in the cylinders and valves, which necessitates frequent cleaning. The working of the engine is irregular and explosive, and in some cases the engine stops through the failure of the ignition of the oil. The results of the experience of a number of users of crude petroleum oils in Diesel engines are discussed by Constam and Schläpfer in the "Zeitschrift des Vereins deutscher Ingenieure." The oils used were principally derived from Galicia, though reference is also made to experiments with crude oils from Germany, Roumania, Russia, America, and Mexico. The Galician oils, ranging in gravity from 0·858 to 0·890, and consisting largely of paraffins, generally speaking, gave no trouble, and were found to be highly satisfactory fuels. In a few cases complaints were made regarding choking of the valves and fuel pumps by resinous deposits; this was traced to the presence of small quantities of a very finely-divided organic solid, which could be removed only by careful filtration. The heavier Roumanian oils, on the other hand, proved less satisfactory. The engine worked irregularly with a sooty exhaust, and, with one of the oils, it stopped frequently on account of the failure of the oil to ignite. After standing over night the orifices were choked with resinous matter, which had to be removed by rinsing with paraffin oil. With none of the three Roumanian oils employed was it possible to start the engine cold. In trials with three Russian oils the engine ran smoothly, but gave an exhaust which was somewhat fouler than that obtained with the Galician oil. Summarising the results of our experience, we draw the conclusion that "any petroleum or petroleum product which is not too easily inflammable, which has a net calorific value not less than 10,000 calories (18,000 B.Th.U's.), and contains neither asphalte nor mechanical impurities, may be used under all conditions as a fuel in the Diesel engine." If the oil gives a considerable residue on distillation or on coking in a crucible, or if it contains much asphalte, it tends to form resinous deposits in the engine; in such a case an increase of the compression and of the blast pressure will effect some improvement.

Amongst the distilled products from petroleum only, gas oil and petroleum spirits have been used extensively for the generation of power, though burning oils, which have hitherto been employed only to a limited extent for this purpose, are likely to be more largely used in motor-engines.

The usual grade of gas oil has a gravity of 0·86 to 0·87, and a net calorific value in the neighbourhood of 18,200 B.Th.U's. per pound. It contains about 86·5 per cent. of carbon, between 12·5 and 13 per cent. of hydrogen, and from 0·3 to 0·5 per cent. of sulphur. It has been extensively used in Diesel engines, and is commonly regarded as a standard oil for this purpose.

Burning oils are used to a limited extent in small oil engines, but their high cost precludes their general use in large stationary engines. Royal Daylight oil has a specific gravity between 0·79 and 0·8, a gross calorific value in the neighbourhood of 20,000 B.Th.U's. per pound, and contains about 85·7 per cent. of carbon and 14·2 per cent. of hydrogen. The continued rise in the price of motor spirit has recently led to the employment of mixtures of petrol and burning oil, and even of the latter alone, as fuel for commercial motor-vehicles, and these mixtures are reported to give no trouble if used in conjunction with a suitable carburetter. The difficulty of starting, which would interfere with the use of these vehicles in traffic, has been overcome by providing them with a separate tank containing petrol, which is used to start the engine.

Motor Spirit—Petrol.—The higher grade of petrol usually has a specific gravity between 0·715 and 0·720 It begins to

*Abstract of paper read before the Institution of Engineers and Shipbuilders in Scotland, January 20th, 1914.
† Petroleum, pp. 214–216.
‡ 1 ton = 7 barrels approximately.

boil at temperatures ranging from 50 to 70 C.—generally in the neighbourhood of 60° C.—and the bulk of the liquid distils over within a range of about 60° C. The proportion which distils over between the temperatures 60° and 120° C. varies from about 85 to 90 per cent. of the total volume. For detailed information regarding the distillation range of commercial samples of petrol, reference may be made to a paper by Blount.* The following statement of the calorific values of samples of commercial petrol is given by Blount (*loc. cit.*) :—

Trade name.	Specific gravity.	Higher calorific value B.Th. U's.		Sulphur per cent.
		$\frac{1}{10}$ gallon.	Lbs.	
Anglo "760"	0·739	14,848	20,092	0·03
Shell	0·717	14,522	20,254	0·06
Pratt's Motor Spirit	0·717	14,492	20,212	Trace
Pratt's Motor Spirit	0·715	14,431	20,268	—
Carless Capel "Standard"	0·700	14,240	20,344	0·06
Carless Capel "Movril"	0·718	14,476	20,160	—
Carburine	0·717	14,438	20,137	—
P.G.R. "720—725"	0·715	14,501	20,281	0·07
P.G.R. "705—710"	0·705	14,326	20,320	—
Russian "Petrol"	0·705	14,253	20,218	0·06

The gross calorific value of commercial petrol may be assumed to range usually from about 20,100 to 20,200 B.Th.U's. per pound; the net value is about 1,400 B.Th.U's. less. The heavier spirits have lower, and the lighter spirits higher values per unit of weight, but, on the other hand, the heating values of the heavier, per unit of volume, are higher than those of the lighter varieties, and a greater duty per gallon may, therefore, be expected from them, provided the carburetter is capable of dealing with them efficiently. There is obviously a limit to the possible increase of the specific gravity, however, as the spirit must be sufficiently volatile to permit of complete vaporisation with air. Preference should be given to a closely-fractionated spirit, boiling within fairly narrow limits of temperature, since this is likely to give a more uniform mixture than one which boils over a wide range.

The use of petrol as a fuel has developed rapidly during the last few years. Deducting exports from imports, the quantity of motor spirit which remained for consumption in Great Britain was, in 1913, 100,000,000 galls. approximately.

In America and France the rate of increase has been even greater, and there is no indication of any slackening of the demand, in spite of the increasing price. The question of the future supply of motor spirit is, therefore, exciting widespread interest at the present time, and is the cause of some anxiety to those engaged in the motor industry. The rate of production of high-grade crude petroleums, capable of yielding motor spirit on distillation, does not greatly exceed that necessary to supply the existing demand. According to Dr. Day, there was a steady drain on stocks during 1912 in all the fields except California and the Gulf, so that from a total of 81,800,000 barrels—representing more than half a year's output—on January 1st, the stocks declined to 69,000,000 barrels at the end of the year, or, in other words, it was necessary to supplement the new production of crude petroleum in the Eastern States of America, during 1912, by taking from stock over 1 million barrels per month, in order to supply the increased demand for petrol. While this decline in high-grade crude stocks was stopped during 1913, and the amount of crude oil in storage was increased in April to the extent of 300,000 barrels above its former level, chiefly by greater activity in the mid-continental field (Kansas and Oklahoma), it is evident that the time is not far distant when the demand for petrol will overtake the possible supply from existing high-grade crude oils.

The threatened scarcity of motor spirit, together with the prospect of continued high prices, has stimulated the search for petrol substitutes to great activity, and the possibilities of benzol, motor spirit from low-temperature tar, shale spirit, and alcohol, have been widely discussed. The present production of 90 per cent. benzol in Great Britain only amounts to about 10 per cent. of the consumption of motor spirit, and, even if all the benzol which is formed from coal in the existing systems of carbonisation were recovered, the total production would still fall far short of the amount necessary to replace petrol, though it would go a long way towards relieving the tension, and would serve as a very useful check on the price of petrol. Regarding the possibility of producing a suitable motor spirit from low-temperature tar by cracking, there is no longer any doubt, but the problem of producing a sufficiently hard marketable coalite or semi-coke, still awaits a satisfactory solution; so long as this remains in doubt, there is no prospect of the establishment of low-temperature carbonisation of coal on a sound financial basis. If, on the other hand, this difficulty is ultimately overcome, as seems probable, one may look forward to the possibility of supplying motor spirit from coal in sufficient quantity to meet all the requirements of the motor industry for many years to come.

In the petroleum industry experiments are at present in progress with the object of increasing the production of petrol by subjecting the heavier oils to a cracking treatment. A process of this kind is at present in operation in Great Britain, whereby solar oil of specific gravity 0·862 is sprayed with water into iron retorts packed with iron filings, and heated to a temperature of 600° C. The yields of final products from 100 gallons of solar oil treated in this way are stated to be 39 gallons of petrol, 13 gallons of solvent spirit, and 13 gallons of a good varnish. The success of such a cracking process will certainly ensure an adequate supply of spirit, but this solution of the difficulty is not entirely satisfactory from the point of view of the motor industry, since it still leaves the control of motor spirit in the hands of the companies which at present control the price of petrol.

These suggestions only offer a temporary solution of the problem of the supply of light liquid fuel, and it is probable that the ultimate solution will be found in the adoption of alcohol. Experiments† have shown that an alcohol engine working under the most favourable conditions of compression (180lbs. per square inch above atmospheric pressure) operates with a fuel consumption practically identical, volumetrically, with that of a petrol engine working at a compression of 70lbs., in spite of the fact that the calorific value of alcohol is only about 60 per cent. of that of petrol. Alcohol is a safer and pleasanter fuel than petrol, and has the additional recommendation that its production is capable of practically indefinite expansion.

The total world's production of liquid fuels of all kinds amounts to less than 55 million tons, of which 47¼ millions are petroleum oils. This total, large as it is, only represents about 5 per cent. of the world's coal production, and the widely-quoted prediction that oil is the fuel of the future has therefore very little prospect of fulfilment. It is true that the oil-bearing regions of the world have as yet been imperfectly explored, and that some areas, known to be petroliferous, still await development, but, on the other hand, the older fields in the Eastern States of America, and in Baku, which supplied the bulk of the world's production of oil for generations, now show unmistakable signs of exhaustion. So far as present information goes there is no justification for the belief that the predominant position occupied by coal as a source of power and heat will ever be seriously threatened by oil fuel.

The position in Great Britain, remote from the principal oilfields of the world, with plentiful supplies of coal in the neighbourhood of the large industrial centres, is particularly unfavourable to the extension of the use of oil fuel. We depend for our liquid fuel largely on the surplus production of other countries, and recent developments point to the disappearance of this surplus in the principal oil-producing countries in the near future. The American production will be readily absorbed by the United States. Russia and Germany will provide a market for the whole of the Russian output, and Austria, with the adjacent countries, is fully capable of disposing of the productions of Roumania and Galicia. Our supplies of petroleum must, therefore, be drawn from the more distant fields, and the limited supply and high freight charges will tend to raise prices to a level at which competition with coal is difficult. For an assured supply of liquid fuel in this country we must depend on the development of the shale oil industry, and the distillation of coal at low temperatures.

* Inst. Automobile Engineers, 10th March, 1909, 1 to 6; Journ. Soc. Chem. Ind., 1909, p. 118.

† R. M. Strong, U.S.A. Geological Survey Bulletin, No. 392.

TESTS OF MODERN HIGH-SPEED BRAKES ON FAST PASSENGER TRAINS.

AT a meeting of the New York Section of the American Society of Mechanical Engineers held on February 10th, an exhaustive paper describing the tests made by the Pennsylvania Railroad last year on the new brakes for high-speed trains developed by the Westinghouse Air Brake Company was read by Mr. S. W. Dudley. The tests are claimed to be the most important and thorough investigation of railway brakes that has taken place since the famous Galton-Westinghouse brake trials in England, in 1878 and 1879. The following is a condensed summary of the paper.

A train of 12 steel passenger cars and modern locomotive weighs nearly 1,000 tons, is about 1,000ft. long, and at 60 miles per hour speed, has a kinetic energy of 224,000,000ft.-lbs. With the ordinary high-speed brake apparatus such a train would be stopped by an emergency application of the brakes in a distance of from 1,600ft. to 1,800ft., according to the truck rigging and brake-shoe design and installation. In making ordinary brake applications for slow-downs or station stops, skill and judgment must be carefully exercised in order to avoid shocks and make short and accurate stops. The Pennsylvania Railroad brake tests of 1913 showed that such a train at 60 miles per hour speed can be stopped by an emergency application in 1,000ft. or within the length of the train. They also showed that trains can be controlled by service applications without shocks at any speeds and with greater accuracy and promptness, and still require less expert knowledge and skill on the part of the manipulator.

The improvement in emergency stopping power has resulted from applying the air brakes more quickly and to a higher pressure, holding this higher pressure without diminution towards the end of the stop, using a more efficient design and better installation of foundation brake rigging, and providing a better method of applying the brake shoe to the wheel and more brake-shoe metal to absorb the heat developed during the process of stopping. The greater efficiency, economy, and flexibility in service has been attained by making the air-brake apparatus more positive and responsive in its operation, both in application and release, enabling full advantage to be taken of all the possibilities of these improvements through the quick, simultaneous, and flexible action obtainable only with electric control, the maintenance of a high and uniform brake rigging efficiency, and the improved truck, journal, and brake-shoe action, less wear of brake shoes and better distribution of forces and reactions accompanying the use of the clasp brake having two shoes per wheel, instead of concentrating the heavy braking forces required by modern equipment on only one side of the wheel.

The tests constitute a scientific study of the brake as a whole; comparing in detail the characteristics of the ordinary high-speed air-brake apparatus with the improved electro-pneumatic brake, the effect of low and high emergency braking powers, the clasp with the single-shoe type of brake rigging, the relative advantages of one and of two brake shoes per wheel, and investigating the limitations of track and operating conditions commonly experienced.

The improved air-brake apparatus, operating pneumatically, shortens the time of obtaining maximum emergency brake cylinder pressure on the train as a whole from 8 secs. with the PM equipment to 3·5 secs., and with electric control this is again shortened to 2·25 secs. Moreover, 125 per cent., 150 per cent., or 180 per cent. emergency braking power is available as may be thought desirable or found permissible, according to circumstances when the installation is made. The PM equipment has an average of 100 per cent. Using 150 per cent. emergency braking power, the quicker and more powerful pneumatic emergency application shortened the stop at 60 miles per hour from over 1,600ft. to about 1,400ft., and the simultaneous action of the electro-pneumatic brake still further shortened the stop to less than 1,200ft.

With the PM equipment the attempt to make an emergency application during the progress of or before releasing a partial or full service application will produce only the same stop as if merely a full service application had been made. Considering the ordinary full-service stop from 60 miles per hour (say, 2,000ft. or 2,200ft.) as 100 per cent.; with the improved apparatus, operating pneumatically, an emergency application following a partial service application will shorten about 14 per cent., and after a full service application about 10 per cent.; with electro-pneumatic operation the gain is 23 per cent. and 15 per cent. respectively. This is a safety factor of great importance.

Shocks during brake applications are due to slack action modified by speed. This was shown by pneumatic and electro-pneumatic stops from both high and low speeds. At high speeds, 60 to 80 miles per hour, the serial action of the pneumatic emergency application resulted in noticeable shocks which increased in severity at lower speeds, and at 10 miles per hour amounted, in effect, to a collision between the rear and forward ends of the train, the train being stopped in 42ft. The simultaneous application of just as great retarding forces by the electro-pneumatic brake entirely eliminated violent slack action at all speeds, the stop even at 10 miles per hour (37ft.) being without shock.

Station stops and emergency stops with the old and the new air-brake apparatus mixed in various ways in the train showed harmony in operation and improved general results, particularly when releasing brakes. Comparative tests showed that when the improved air-brake mechanism is used on the cars, an arrangement giving a high emergency braking power on the locomotive, with blow-down feature, reduces shocks due to unequal braking power and shortens the stops. With the electro-pneumatic brake a uniform increase in maximum per cent. braking power results in a substantially uniform decrease in length of stop, the decrease amounting to about 2 per cent. for each 5 per cent. increase in braking power within the range of these tests.

The available rail adhesion varies through wide limits; *e.g.*, from 15 per cent. in the case of a frosty rail early in the morning to 30 per cent. for a clean, dry rail at mid-day. Wheel sliding depends more on the rail and weather conditions than on the per cent. braking power. Some sliding was experienced with braking powers as low as 90 per cent. when rail conditions were unfavourable, but 180 per cent. braking power did not cause wheel sliding with a good rail. The effect of excessive wheel sliding was to make the length of the stop about 12 per cent. greater than similar stops without wheel sliding.

An expression for the relation between coefficient of rail friction f_r, efficiency of brake rigging c, and per cent. braking power P at the instant wheel sliding is about to occur, derived from the data of the best tests made, is $P^{0·531} = \frac{8·33 f_r}{e}$.

An efficient design of clasp-brake rigging was shown to be necessary in order to avoid serious losses due to excessive piston travel, undesirable journal and truck reactions, brake-shoe wear, and variable shoe action. The performance of the cast-iron brake shoe was shown to vary between wide limits, the ordinarily assigned causes for this variation (such as speed, pressure, and time of action) becoming effective chiefly as they affect the temperature of the working metal of the brake shoe and wheel.

The amount of wheel and shoe metal in working contact during a stop is very small, and is the most difficult factor to control. At the same time, it is most potent in producing variations in brake performance. The brake-shoe bearing area, and consequently the generation of heat in the working metal and the resultant coefficient of friction, was shown to vary considerably during the progress of a single stop, and to a greater degree as the fit of the shoe to the wheel changed due to warping or continued rubbing. Due to this effect alone the emergency stopping distance at 60 miles per hour changed by as much as 20 per cent. There is evidence, however, that with reasonable attention to brake-shoe maintenance the condition of the shoes on cars in ordinary road service is likely to be more favourable to making short emergency stops than during a series of tests in which the brake shoes are worked severely.

Flanged shoes provide more available area for bearing than unflanged shoes, and, when worn in, shortened the train stops about 12 per cent. The use of two shoes instead of one per wheel will result in a higher coefficient of friction and less wear per unit of work done, the durability under clasp-brake conditions being about 40 per cent. greater than under single-shoe conditions. The use of two shoes per wheel permits a design of rigging which will enable flanged shoes

to be used without danger of pinching flanges and causing excessive flange wear or non-uniform brake forces, which result when flanged shoes are used with rigid beam connections. The wear of flanged shoes is about 20 per cent. less than unflanged shoes.

From tests at 60 miles per hour with clasp-brake rigging, the relation between coefficient of brake-shoe friction f_s and per cent. braking power P was found to be $f_s = \frac{0 \cdot 12}{P^{0 \cdot 42}}$. No satisfactory separate determination of brake rigging efficiency e, and coefficient of brake-shoe friction f_s, was made during the road tests. The combined effect $e \times f_s$ was obtainable with reasonable accuracy from the best of the several stops made under various conditions as given in the following table. The values for single-shoe conditions are more uncertain than the clasp-brake conditions due to less satisfactory data.

Values of $e \times f_s$.

Kind of brake rigging. Type of brake shoe.		Clasp brake.		Single shoe.*	
Speed, m.p.h.	% braking power.	Plain.	Flanged.	Plain.	Flanged.
30 ..	125	0·141	0·169	0·108	0·112
	150	0·129	0·154	0·099	0·103
	180	0·118	0·141	0·090	0·094
60 ..	125	0·103	0·122	0·074	0·090
	150	0·094	0·112	0·068	0·082
	180	0·086	0·102	0·062	0·075
80 ..	125	0·092	0·109	0·070	0·074
	150	0·084	0·100	0·064	0·068
	180	0·077	0·092	0·059	0·062

*Value of data uncertain due to non-uniform brake-shoe conditions.

The length of emergency stop S_t on a straight level track, neglecting air and internal friction on the one hand and the rotative energy of the wheels and axles on the other hand, can be calculated from the following formula:—

$$S_t = 1 \cdot 467 \, Vt + \frac{V^2}{30 \, P \, e \, f_s}$$

in which

V = Initial speed in miles per hour.

P = Per cent. braking power actually realised.

$e \times f_s$ as determined by the existing brake rigging and shoe conditions (see table).

t = Time at the beginning of the stop during which the brakes are to be considered as having no effect, to allow for the time element in the application of the brakes.

Kind of Air Brake Equipment.

For a 12 car train.		P.M.	UC. Electro-pneumatic.
t ranges	from	2·0	... 0·70
	to	2·5	... 0·85

A train of 12 steel cars and locomotive with the electro-pneumatic brake, 150 per cent. braking power, clasp-brake rigging, unflanged brake shoes, can be stopped: From 30 miles per hour in 200ft., equivalent to an average retarding force of 300lbs. per ton. From 60 miles per hour in 1,000ft., equivalent to an average retarding force of 240lbs. per ton. From 80 miles per hour in 2,000ft., equivalent to an average retarding force of 214lbs. per ton.

The Junior Institution of Engineers: North-western Section.—At a meeting of the North-western Section of the Junior Institution of Engineers in the Scientific Society's Room, Manchester Municipal School of Technology, Mr. C. H. Prichard in the chair, a paper was read by Mr. Herbert Smith on "High-speed Engines." The author treated his subject from the standpoint of a consulting engineer, advising a client with regard to the reliability and cost of a prime mover. By the aid of lantern slides, various types of high-speed engines by the leading makers were illustrated and discussed, curtailment of engine-house space and instances of long runs being points chiefly brought out. An interesting discussion followed.

UPKEEP AND MANAGEMENT OF BOILERS ON A TRAMP STEAMER.*

BY G. A. O'NEILL.

THE upkeep of a boiler depends a great deal on the management of it, and it is generally understood that the successful management of a boiler consists in getting the desired results with as low a cost as possible. To be able to do this it should be handled with proper care, and any defects showing should be remedied at once, or at the first opportunity, and their causes removed.

Internal Corrosion.—The greatest source of trouble with boilers is internally, through corrosion, and the depositing of scale on the heating surfaces. Internal corrosion may arise from various causes, viz., impurities brought into the boiler with the feed water, air in the feed water, mechanical straining, in many cases through galvanic action being set up between two classes of metal in the construction of the boiler. If sufficient interest and care is taken, internal corrosion may be prevented to a greater extent than is often the case on tramp steamers, by the present means available for stopping or reducing it, such as the use of zinc plates, keeping the feed water as hot as possible for liberating the air, and adopting the use of alkalies (soda) in the proper manner.

Sufficient care is not always taken when fitting zinc plates into the boiler, by cleaning away the dirt and scale from around the necks of the studs, to which they are at some parts fitted, so as to ensure a proper metallic contact. If this is not done the dirt or scale acts as an insulator, and so destroys the object for which they are used, viz., in setting up galvanic action between the zinc and the boiler plates. It is a simple matter when fitting these plates to give the studs a touch up with a file.

The use of soda is an aid for the prevention of corrosion, or rather, in reducing the acidity of the water. This is very often used without any consideration as to the amount required. If an engineer knows his boilers were properly cleaned and a necessary amount of zinc plates fitted when leaving port, by the use of litmus papers he can get an idea as to whether he is putting sufficient soda or otherwise into the boilers on the passage. A small quantity of water can be drawn off at the salinometer cock, and the litmus papers inserted; if the blue paper turns pink and the pink paper remains unchanged, the water contains acid; if the result is the opposite the water is alkaline in nature.

By careful treatment of corroded plates in a boiler they can often be prevented from further deterioration; for instance, the pitting that is frequently found going on, along and a little above the line of firebars, on the water side of a furnace. These places, if thoroughly cleaned and the black scale removed, then coated with a mixture of metallic zinc powder and clean fresh water, will show good results, but it must be kept up and the same places done over again after every long passage.

Corrosion often sets up on the front end plates and the front end of the main stays in the steam space on the side of the boiler to which the uptake is fitted. Some engineers, to arrest this, suspend zinc plates from the stays by means of iron hangers. The presence of zinc no doubt is an advantage, but this method is not an advisable one, owing to the liability of the zinc plates to break, falling off the hangers, and landing on the top of the furnaces. A good method is to fix iron boxes on the stays and let the zinc plates rest in them. Good results have been obtained by filing the ends of the stays clean, and cleaning the front end plates as before stated on the furnaces, and painting them with zinc white, but this also must be kept up.

It is quite a general practice when scaling furnaces to only scale them down to the line of firebars, leaving the entire bottoms untouched, and scale is allowed to form to a considerable thickness and left on for voyage after voyage. This I consider to be a very bad practice, as corrosion has been found going on badly under this scale on the furnace bottoms, which, had the furnaces been kept cleaned right round, might not have ever started; in any case, it would have been seen at the commencement, when steps could have been taken to remedy it.

The backs of combustion chambers and the necks of the stays at the combustion chamber end give another source of

* Paper read before the Institute of Marine Engineers.

trouble due to corrosion, and require every attention and care. When corrosion has once started here it is hard to stop owing to its inaccessibility. Probably, the best means of stopping it is to clean the parts as well as possible and fasten zinc plates to the stays, midway between the boiler end plate and the combustion chamber back.

Internal Feed Pipes.—These pipes, when fitted, should be given every attention, as the position in which the feed water is discharged into a boiler has a material effect on the circulation, which leads to show that should they be allowed to remain in a bad state of repair it would mean loss of efficiency. They often give trouble by continually bursting, and in many cases, if not well secured by clamps, come off altogether. This may be said to be due to water-hammering, caused by the internal pipe becoming partly filled with steam, and the feed pumps, every stroke, delivering comparatively cool water, producing a concussion by the sudden condensation of the steam, which forms a vacuum in the pipe and causes an inrush of boiler water. In Mr. Stromeyer's book on boilers it is stated that a small hole near the flange on the pipe or an uncemented joint entirely prevents this action. This has certainly been found to work well with the uncemented joint, but with copper internal pipes another trouble arises. Corrosion sets up badly on the boiler plate to which the brass flange of the pipe is jointed, also the studs when of iron or steel get corroded; this is undoubtedly due to galvanic action between the copper pipe or brass flange and the boiler plate and studs. It is therefore necessary that this joint should be kept tight when copper pipes are fitted. Another advantage gained by internal feed pipes is that the feed water passing through them becomes heated before being discharged, and further loses any air it may contain.

In modern ships the foregoing troubles are somewhat eliminated by the fitting of independent feed pumps and efficient feed heaters where the feed water is delivered into the boilers at over 200° Fah., practically free from air. Impurities are further extracted by the use of modern feed-water filters, and with a good evaporator the use of salt water feed is reduced to a minimum; but in the class of ship to which I am referring, where the feed water is dealt with solely by the main feed pumps, the highest temperature at which the feed water can be pumped into the boilers is seldom over 150° Fah., and although evaporators and filters are fitted, it is, in many cases, found necessary to work the boilers at about 5 ozs. density, to keep a protective scale on the plates, especially with new boilers.

Raising Steam.—When commencing to raise steam it is quite a common rule with many engineers to set the fire away in the centre low furnace of a three-furnace boiler four or five hours before the others, in the hope that the cold water which remains undisturbed at the bottom will get warm. This rule undoubtedly originated in old ships, where there were no appliances fitted for artificial circulation, such as hydrokineters, or a suction pipe from the boiler bottoms to a feed donkey pump. With these appliances I consider the above practice unnecessary, as it must set up an undue strain on the front end plate by the centre furnace becoming heated and expanding, and the two wing furnaces remaining cold and rigid, to which may be attributed the cause of leaky furnace mouth seams when happening under such circumstances. For this reason all fires should be lighted together, especially when there are means of promoting artificial circulation.

Too much care cannot be taken in attending to the circulation when raising steam. When the fires are set away the safety valves should be opened to allow the heated air in the steam space to escape. (Another plan is to ease the stop valves off the face and allow the heated air to pass through and warm up the engines, but this is not always convenient). If this is not done the air forms a pressure, and this air pressure on the surface of the water prevents the formation of steam bubbles when boiling point is reached, which would materially assist the circulation by carrying water with them as they rise. The safety valves should be left open until steam is blowing through them, and the hydrokineters or donkey pump, as the case may be, kept working, until the boiler bottoms have grown quite hot.

It is often the case that after steam has been raised it has not been wanted for some time, through delay, and with the boilers standing and no circulation going on the bottoms will become quite cold, even when the steam is at working pressure. If a donkey pump is the only means for circulating, difficulty will be found in getting it to work, if at all, with high pressure on the boilers. To guard against this drawback, it is always advisable to fill the boilers up full glass, and blow off the cold water from the bottoms at intervals. Should there be no delay, it is still an easy matter to blow the water off before starting. This method of blowing might be adopted when lying under banked fires, especially when fresh water is obtainable for making up the loss.

If the boilers are allowed to stand long with their bottoms cold, under pressure they are sometimes unable to bear the additional straining to which they are subjected, by the difference of temperature between practically the upper two-thirds and the lower one-third of their circumference, and if not causing a cracked shell plate it is invariably the cause of leaky circumferential seams, which, when once started, are a trouble to keep tight ever after. This difference of temperature can amount to considerably over 250° Fah., and as iron expands ·0012 and steel ·0011 of their length between 32° Fah. and 212° Fah., it can thus be seen, that with a large boiler, a severe stress would be set up. Siemens steel has now taken the place of iron in boiler making, and as it possesses a much higher tensile strength, together with greater elasticity, the danger of cracked shell plates is considerably reduced, but, as the percentage of strength of the circumferential seams is comparatively low, the danger of sheared rivets and leaky seams has still to be guarded against.

External Corrosion.—In dealing with the external parts of a boiler, there are many things in the management to which sufficient care is not always given with a view to the preservation and upkeep of the boiler. The bottoms of combustion chambers on the fire side, for instance; here an incrustation of scale and dirt, if not watched, will form, and with the combustion chambers being frequently swept and scraped out, this scale obtains quite a smooth surface and appears like the plate itself. It can easily be detected by a tap with the round end of a hand hammer, when it will break off in flakes. If this is allowed to form, corrosion invariably goes on underneath it, and the thickness of the plate is sometimes seriously reduced before being noticed.

Salt from leaky tubes and joints, when mixed with wet ashes, causes corrosion, and as this often occurs in the combustion chambers, it is essential that any leaks noticeable should be stopped at the first opportunity. The boiler front end plates at the bottom suffer a great deal by wet ashes coming in contact with them. This cause can be eliminated to some extent when at sea, if the ashes are removed from the furnace fronts immediately after the fires are cleaned, and not allowed to remain there until the end of the watch, as is often the case.

Great care should always be taken when putting on bottom manhole doors to ensure a good joint. These doors, when leaking constantly, cause the flanges of the plate to get corroded away, which, in time, renders it impossible to make a proper joint. This trouble is further influenced by the presence of wet ashes, when the manholes are in the stokehold. More often than not, ashes accumulate on the manhole flanging, between the "dogs" of the door, and any salt leaking from the joint forms a solid mass with the ashes on the door, and might remain this way when on a long passage for weeks, corrosion going on all the time. This leads to show that they should be looked at daily at sea, and any signs of accumulation of dirt at once removed.

Furnace doors being in constant use soon get out of order, and, as they are an important item regarding economy, it is necessary that they should be kept in proper repair. If not kept properly fitted with baffle plates, they soon become warped with the intense heat to which they are subjected. The difficulty then arises in getting them to shut closely, and cold air is allowed to be admitted into the furnaces to excess, and so reduces the efficiency of the boiler.

Institution of Automobile Engineers. At a meeting recently held in Glasgow of engineers interested in the automobile industry it was decided to form a Scottish section of the Institute. Mr. T. C. Pullinger was elected chairman of the section.

BRITISH COAL SUPPLIES.

PROFESSOR CADMAN, of Birmingham University, in the course of a lecture on "Coal Mining: Past, Present, and Future," at the Midland Institute, said that within the last 36 years the annual production of coal in the different countries of the world had quadrupled, rising from 277 million tons in 1878 to over 1,000 million tons in 1911; and in Great Britain the output had reached 272 million tons. Our coal resources were supposed to be capable of yielding 193,000 million tons. That figure was arrived at after an exhaustive and extensive enquiry conducted by a Royal Commission on Coal Supplies in 1905, and it appeared that the coal resources, or rather the fuel resources—because in the near future we should probably be using products of coal in a manner, perhaps, that we did not recognise to-day—were assured for a considerable number of years. But such an estimation could be only tentative. New discoveries and developments in science would necessitate frequent examination of our fuel resources. The subject, indeed, was of national importance, and we were apt to treat it with considerable indifference. A permanent arrangement should be made to enable the Government and the public to be kept in intimate touch with the available resources of its premier industry.

The future of coal-mining in this country was wrapt in problems of extraordinary difficulty. Those of a mechanical nature did not cause much anxiety, for engineering science had developed at such a pace that it was not likely to fail to meet the call upon it in that direction. The control of temperature in deep mining of the future was one of the most difficult problems that had to be met. It was one which posterity would have to face. The question of coal-dust explosions was also touched on by the lecturer. How were these calamities to be stopped? The problem appeared to have been solved, and the remedy, apparently, was quite a simple one. The committee which had been working on the subject had shown after extensive experiments that for practical purposes the adulteration of the coal dust with some incombustible dust, some powdered stone dust to the extent of about 50 per cent., was all that was required. By the proper application of that remedy on systematic lines they would be almost entirely relieved from those lamentable accidents. Unfortunately, however, regulations were not sufficient entirely to meet the object. The regulations would not effect a remedy unless an intelligent anticipation of the problem was realised not only by employers but by employés.

Speaking of subsidences, Prof. Cadman said it was only when mines were worked in an irregular manner that the surface was let down to any serious extent. In order to fill the holes caused by the removal of coal, hydraulic stowing had been devised, a method which consisted in flushing débris from the surface and carrying it into the holes. This method would permit of great developments in this country, particularly where new undertakings were set up. It would mean that more efficient extraction would be possible, with less consumption of timber, fewer accidents from falls, greater ease of ventilation, and less subsidence. Of course, it would mean an increase in the price of the product, but that was something all were prepared for.

TESTING MACHINE FOR LARGE-SIZE GIRDERS.

THE Director of the U.S. Bureau of Standards of the Department of Commerce has, according to "The Iron Age," asked Congress to provide in the annual Sundry Civil Appropriation Bill an appropriation of £20,000 to begin the construction of the largest transverse testing machine ever constructed. The total cost will approximate £80,000, and it will be housed in a special building to be constructed at an additional cost of about £50,000. This testing machine will weigh more than 200 tons and will be constructed to test to destruction plate and other girders up to 75ft. in length and 12ft. in depth, also full-sized brick and concrete arches and floor construction.

The testing machine will be of massive construction and will be supported by four large screws, 16in. diam., carrying a loading mechanism capable of loading the girders uniformly or at as many points as may be desired. The load will be applied by means of hydraulic cylinders, but the weighing device is of the lever type and is entirely distinct from the loading device. Tentative designs have been prepared for the machine, but these will be modified and adapted in accordance with the expressed needs of engineers when the appropriation is secured. An important feature of the designing of this gigantic testing machine will be the consulting of engineering authorities throughout the country in order that the machine may be so built as to be available for all projects for which it is generally designed. While the new machine will be the principal appliance to be housed in the special building, considerable other heavy testing equipment will be assembled under the same roof, as it is the intention of the director to bring appliances together to place the structural material work of the Bureau of Standards on a basis somewhat commensurate with the needs of the engineers of the country.

The Bureau of Standards has recently put into operation its large tensile and compression machine of the Emery type, and is now engaged upon a series of tests of columns according to a programme arranged by the Column Committee of the American Society of Civil Engineers. In this connection several columns presented by the American Railway Engineering Association are being tested. A collateral investigation is now progressing at the Pittsburg branch of the Bureau of Standards, where similar programmes are being carried out in connection with the 10,000,000lbs. compression machine there installed.

THE JUNIOR INSTITUTION OF ENGINEERS.

THE 30th annual dinner of the Junior Institution of Engineers was held at the Holborn Restaurant on Saturday last, the president, Sir Boverton Redwood, Bart., D.Sc., F.R.S.E., presiding. Proposing "The Petroleum Industry," Sir Oliver Lodge said that in future engineers would be more associated with the operations of the oil industry than they had been in the past, and he took it that it was the realisation of that which had caused the Institution to elect Sir Boverton Redwood to their presidential chair. Sir Oliver referred to the Admiralty as a very good customer of engineering, and added that he could not but regret the immense amount of ingenuity, skill, scientific knowledge, and expenditure put into the work of death and destruction. If the same amount were expended in a scientific laboratory it would result in discoveries of vast importance to mankind. The country that allowed itself to get behind in scientific progress and discoveries was going to take a back seat. Great Britain, he said, had to wake up in that respect, and realise that while we were rich enough to have good engines of defence, we must also be rich enough to explore the secrets of nature. The importance of the petroleum industry, not to our nation only, but to all nations, was being recognised by the Governments of these countries, but not least by our own Government. Sir Boverton Redwood, in responding, said that in the petroleum industry there had been no lack of leaders, and they had every reason to be proud of the part that British engineers had played in the development of oilfields in various lands. But to our shame he had to say that whilst there had been leaders, it had been occasionally difficult to find men properly qualified to take part in the work initiated by the men to whom he had referred, and it had often been necessary to go abroad in order to find men effectively trained to take part in this important work. He was of the opinion that the University of Birmingham, in instituting a special curriculum for the training of students in petroleum mining, leading up to the degree of Bachelor of Science in Petroleum, have performed a signal service which ought to be generally recognised as one which it is desirable to support in every possible way. Mr. Ernest King, responding for "The Institution," which was proposed by Prof. Meldola, said that the total membership had now reached 1,272, by an almost unbroken record of progress. In the first five months of the present session the membership had increased by the extraordinary number of 101 net, as against an increase of 35 for the whole of last session.

INDUSTRIAL AND TRADE NOTES.

Clyde Shipbuilding.—During the past month 21 vessels were launched from Clyde shipyards, having a total tonnage of 19,082, as compared with 11 vessels of 22,272 tons in January. Owing to the depression in the freight market, very few orders were placed for new work.

German Machine Tool Industry in 1913.—According to "Stahl und Eisen," the results of most of the companies in the Union of German Machine Tool Makers were satisfactory for 1913, and in many cases better than in 1912. Business was also carried on right up to the autumn at remunerative prices. Even in the last quarter business was on the whole good, but the demand slackened noticeably during that period, and also, on account of the falling off of iron and steel prices, the prices originally demanded for the machines could not be maintained. The conclusion of the year was therefore a little less favourable than the beginning. The exports of machine tools, the largest of all the branches of the German machine industry, showed a distinct increase, rising from 72,000 metric tons in 1912 to 87,000 metric tons last year. The total exports of machinery (other than electrical) increased by 55,000 metric tons to 594,000 metric tons in 1913.

Conciliation in Labour Disputes.—A record number of cases was dealt with by the Board of Trade during 1913 under the Conciliation Act of 1896. The year's total was 99, against 73 in 1912, and 92 in the previous record year, 1911. The most important disputes in which action was taken were the strike of metal workers in South Staffordshire and North Worcestershire, and the strike of transport workers, &c., in Dublin. The former dispute commenced in April, and affected directly or indirectly about 50,000 workpeople, the demands involving a claim for a minimum wage of 23s. per week. A settlement was arrived at in July. The Dublin strike began with the tramwaymen on August 26th, and involved about 20,000 persons by the end of September. The report details the unsuccessful efforts to settle the dispute, and adds that a general resumption of work occurred towards the end of January and the beginning of February. Of the 99 cases dealt with, 53 involved a stoppage of work Since the Act came into force in 1896 a total of 696 cases have been dealt with, about 65 per cent. of these having occurred during the last six years. The record established in 1911 was due to the sudden rise in transport cases from 3 to 21, and that last year to an increase in the building trades from 10 to 31. The total number of voluntary conciliation boards and standing joint committees in existence at the end of 1913 was 325.

State Ownership of Mines.—At a recent meeting of the Newcastle Economic Society, Prof. Louis, M.A., D.Sc., in a lecture on "Nationalisation of Mines and Minerals," pointed out that in the only State-owned coalfield in this country, the Forest of Dean, the men's wages and conditions were no better than in any other part of the country. Indeed, the men were paid lower wages. Nor was the coal sold at any cheaper rate. He also instanced the cases of the royalties owned by the Ecclesiastical Commissioners, and drew comparisons in favour of privately-owned mines against State-owned mines, both in regard to wages and conditions, in Westphalia and in a State-owned mine in Victoria, Australia. The Professor referred to the trouble which had occurred over the State railways in South Africa, and said he thought that an object lesson which should be sufficient to deter the most enthusiastic advocate of mines nationalisation. He mentioned that in the House of Commons recently the Labour party had moved an amendment to the address of the Throne because the legal interference with mines during the last three years had not brought the miners any benefit. Now they saw orders for coals going to Westphalia, which had hitherto come to this country, because of the increased cost of production due to these useless legislative restrictions. He protested against the argument that under a national system there would be greater safety of mines. Such a statement was, he said, a reflection upon the care which was taken by the mine owners of this country at the present day.

The Shipping Outlook.—At the annual meeting of the Chamber of Shipping of the United Kingdom, held in London on February 27th, Mr. J. H. Warrack, the president, in the course of his address, said that he regretted he could not congratulate them on the present condition and future prospects of merchant shipping. At the moment it was evident that the increased additions to the world's tonnage during the last three years, combined with a shrinkage in the carrying requirements and the release of a large number of steamers which had been engaged on time charter to regular lines, had turned the scale in favour of the merchant, and probably the fact that owners were not now acting with the same confidence had helped to accentuate the severe drop in rates which they had experienced during the last few months. Not only had rates of freight materially decreased, but owners had now to face higher running expenses, from which they were not likely to obtain much relief for some time. While the outlook therefore was far from promising, it was a mistake to take too gloomy a view of the situation. Shipping generally was in a much sounder financial position to-day than for many years, and it was to be hoped that this circumstance would assist owners to make a better stand against the efforts made unduly to depress rates and enable them to face the only remedy, the laying up of tonnage rather than run at a loss. No doubt the tonnage put into the water during the last three years and the heavy amount under construction would take some time to work off, but if owners who were not compelled to build tonnage to maintain their regular lines would refrain from placing orders for the next two years they would not only do much to restore a higher level of rates, but they would then be able to buy at considerably lower prices. The great development which had taken place in the merchant fleet of the world during the last 25 years was strikingly shown by the fact that in 1888-89 there were 9,890 steamers with a total gross tonnage of 10,918,153 tons, and in 1913-14 there were 23,897 steamers of 43,079,177 tons, an increase of 32,161,024 tons, or almost 300 per cent. To add to the difficulties of conducting business with freights at a much lower level there was the uncertainty and loss caused by frequent labour disputes. The suggestion had been made that strong conciliation boards might be formed to prevent disputes coming to a head or secure a settlement should a strike take place, but employers would hesitate to adopt such a method unless they could be assured of the competence and absolute impartiality of such boards, and that their decisions would be accepted as binding by the employed as well as the employer. Meanwhile the only course open appeared to be to press for amendment of the Trades Disputes Act of 1906, and to urge the Government to protect from intimidation those who were willing to work.

Army Aeroplanes.—In the House of Commons a few days ago Col. Seely (Secretary for War) gave some interesting information relating to the development and use of aeroplanes in the Army. He stated that on July 30th last they had 113 aeroplanes for the Flying Squadron and for the Flying School. Since that date they had struck off 52 and had added 100 new aeroplanes, making a total now in possession of 161. The striking off of 52 machines seemed a strong step, but it was perfectly justifiable. The machines they had a year ago were nothing like as good as they had now. This step had been taken to minimise the risk to life and limb, and it had had that result. Since July 30th the number of miles flown was well over 100,000. During that time, excluding Saturdays and Sundays, which were not flying days, there had only been six days on which flying had not taken place, and there had not been one single fatal accident to an officer or man of the Royal Flying Corps, and there had been no case of any serious breakage of a main part in the air. The creation of an inspection branch was to see that machines were carefully tested in every part. They had made arrangements for accelerating the provision of the squadron, and would require 250 aeroplanes—50 for the central flying school and 200 for the military wing. They had come to the conclusion that if they wanted to have 10 aeroplanes ready at any given moment, they must have 20 in their possession. The great majority of the machines were biplanes. They could not count the life of an aeroplane as more than two years, so they would require 125 new machines a year to keep up the supply. These could be got in the United Kingdom. Of the 100 obtained since July, they got 13 from abroad and 87 in this country. He had satisfied himself that the condition of the industry was such that they could quite easily get all the aeroplanes they required in this country. With regard to engines, a competition was to be held in the near future, with a considerable prize, and orders to the extent of £50,000 for a British-built engine. He believed they could also get all the engines they required in this country in a short space of time. They proposed that much the larger proportion should be constructed by private firms. The smaller proportion would be constructed by the Royal Aircraft Factory, leaving them free to make experiments and to construct machines of a special type, of which they did not wish the details to become known. They had nothing to fear as to the capacity of this country to produce the machines and engines required. The average speed of their machines was 65 to 66 miles an hour, which was much greater than the average speed of the aeroplanes of any other country. There could be no doubt as to the usefulness of these machines. The power of vision from the air was astonishing At a height of 5,000ft. one could see clearly on an ordinary day every detail of the landscape. On the whole, he believed they had made very satisfactory progress, and they hoped to make still further progress in the year to come.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1912.

Internal combustion engines. Redrup, Boyle, Boyle, & Redrup. 25452.
Power hammers. Pettingell Machine Company, and Knight. 25789.
Safety apparatus for arresting pit cages and hoists. Hanley. 28781.

1913.

Internal combustion engines. Fullagar. 603.
Manufacture of chains with welded links. Bindel. 2785.
Apparatus for controlling or regulating the speed of railway trains. Ward. 2981.
Piston valves for pumps. Duverger. 3059.
Nut-locking devices. Thompson. 3086.
Apparatus for raising water. Paindavoine. 3295.
Centrifugal governors. Clark. 3328.
Apparatus for converting reciprocatory motion into rotary motion. Wade. 3338.
Cast iron and process for producing same. Anderson. 3354.
Motor-driven vehicles. Norton. 3369.
Variable-speed mechanism. Giles & Giles. 3492.
Heat radiating device applicable to internal-combustion engines. Wharrad Engineering Company, and Wharrad. 3493.
Manufacturing cement steel. Benjamin. 3554.
Change-speed gear mechanism for motor-vehicles. Stratton. 3674.
Revolving cylinder internal combustion engines. Baird & Turner. 3710.
Apparatus for the automatic production of non circular holes. Lauterjung. 3756.
Manufacture of products of indefinite length from molten lead or other metals or alloys. Debauge. 3944.
Production of gaseous fuel. Southey. 4006.
Elastic fluid turbines. Warwick Machinery Company (1908). 4092.
Carburetters for internal combustion engines. Roots. 4503.
Centrifugal pump or fan. Johnston, and Globe Pneumatic Engineering Company. 4661.
Boiler furnaces. Thomas. 5674.
Apparatus for treating boiler feed water. Genssen & Wiebelitz. 5949.
Carburetters for internal-combustion engines. Hammond. 6063.
Muffle furnaces. Curran. 6165.
Lubrication of internal-combustion engines Neute. 6374.
Penstocks and valves. Adams. 6417.
Centrifugal fans. Hancock. 7492.
Internal-combustion engines of the sleeve-valve type. Burt and Matthew. 7879.
Heating or condensing apparatus. Dahl. 8217.
Apparatus for governing the speed of railway trains. Alexander. 8245.
Diaphragm pumps. Bentall & Bingham. 8345.
Manufacture of ammonia and other by-products in gas producers. Wade. 9499.
Revolving-cylinder reciprocating engines. Southall. 9525.
Starting of internal combustion engines. Purday. 10206.
Promoting combustion in boiler furnaces. Stewart. 10234.
Centrifugal pumps. Mond. 11314.
Reverberatory furnaces. Soc. Francaise D'Exploitation de Fours Speciaux à Haute Temperature. 11390.
Removing soot from fire tubes of steam generators. Grunwald. 11732.
Retort furnaces. Londress & Worley. 11900.
Carburetters for internal combustion engines. Dicker. 11969.
Internal-combustion engines. Tugwood. 12352.
Two stroke cycle internal combustion engines. Brettell. 13397.
Speed-changing gearing. Wardwell. 13880.
Railway rail joints. Allen. 14024.
Optical indicator for internal combustion engines and steam engines. Dalby & Watson. 14108.
Rock drills. Meyer. 14637.
Fluid-pressure motors for driving torpedoes. Soc. des Moteurs Salmson. 15303.
Variable-speed and reversing gearing. Mortier. 15522.
Method of separating barytes from ores. Greenstreet. 16273.
Rotary explosion engine. Dupont. 16631.
Pipe wrenches. Gealy. 17673.
Means for supplying actuating fluid to the cylinders of haulage machines. Wood & Wood. 18114.
Boiler circulators. Fraser. 18861.
Cardan joints. Soc. Anon. Usines Pipe. 18938.
Steam jet apparatus. Miersbe. 19226.
Transmission gearing for automobile vehicles. Mellersh Jackson. 19259.
Internal combustion engines. Shillito & Wallwork. 19639.
Apparatus for filtering dust from air and gases. Allday & Collins. 19695.
Annular ball bearings. Schatz. 19741.
Automatic starting device for explosion engines. Gay & Pauilhac. 20842.
Detachable fastening devices for flexible stays. Vickers, Ltd., and Challenger. 21232.
Change-speed gearing for motor road vehicles. Stewart and Williams. 22624.
Burner for autogenous welding and cutting of metal. Kongsbak. 22923.
Power transmission means. Fournier. 23846.
Control device for rotary boiler feed pumps. G. & J. Weir, Ltd., and Petermöller. 24073.
Anti-friction bearings. Greene. 24582.
Reheating furnaces. Siemens. 28048.
Regenerative coke ovens. Schuster. 29517.

ELECTRICAL, 1912.

Electrical ignition. Biddlecombe & Thomas. 28513.

1913.

Transmission of electric signalling impulses through cables. Williams. 788.
Means for generating alternating electric currents. Marconi. 802.
Electrical control of alternating-current motors. Otis Elevator Company. 3249.
Telephone systems. Automatic Telephone Manufacturing Company. 3339.
Electric motor control systems. British Thomson Houston Company. 3565.
Suppressing the interruption arc on electric switches. Burstyn. 3882.
Inter communication telephone systems. Sterling Telephone and Electric Company, and Bell. 4396.
Electric machines having commutators. Ljungström & Widström. 4773.
Controller for electric lifts and hoists. Cooper & Barlow. 4869.
Electrical contact devices particularly applicable to arc lamps. Brockie, and Johnson & Phillips, Ltd. 4927.
Magazine electric fuse box. Groves. 6861.
Electric lighting of vehicles. Lee & Oldfield. 7286.
Prepayment apparatus for the supply of electricity. Garside. 7853.
Automatic telegraphic apparatus. Gell. 14407.
Telephone relays. Schiessler. 15179.
Automatic telephone exchanges. Reeves & Lundell. 15579.
Dynamos. Brooks & Holt. 15697.
Rectifiers for alternating electric currents. Richardson. 19668.
Trollies or collectors for electricity Wallace & Macey. 20284.
Submarine electric lamps. Davis. 21115.
Actuating electric apparatus at a distance. Widegren & Widegren. 29240.

METAL QUOTATIONS.

TUESDAY, MARCH 3RD.

Aluminium ingot	86/- per cwt.
,, wire, according to sizes, &c. ......from	112/- ,,
,, sheets ,, ,, ... ,,	112/- ,,
Antimony £27/10/-	to £29/10/- per ton
Brass, rolled	7½d. per lb.
,, tubes (brazed)	9⅝d. ,,
,, ,, (solid drawn)	8¼d. ,,
,, ,, wire	7⅝d. ,,
Copper, Standard	£64/-/- per ton.
Iron, Cleveland	50/6 ,,
,, Scotch	56/6 ,,
Lead, English	£20/5/- ,,
,, Foreign (soft)	£20/-/- ,,
Mica (in original cases), small	6d. to 3/- per lb.
,, ,, ,, medium	3/6 to 6/- ,,
,, ,, ,, large	7/6 to 11/- ,,
Quicksilver	£7/10/- per bottle
Silver	26 11/16d. per oz.
Spelter	£21/7/6 per ton.
Tin, block	£173/-/- ,,
Tin plates	13/3 ,,
Zinc sheets (Silesian)	£25/-/- ,,
,, (Stettin; Vieille Montagne)	£25/2/6 ,,

The Mechanical Engineer.
AN ILLUSTRATED WEEKLY JOURNAL
Vol. 33, No. 842.

Edited by
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Telegrams: "Scientific," Manchester.
Telephone No. 6055 City.

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Steel Driving Belts.

SOME of our readers will be aware that in connection with investigations that have been made by the Mill-driving Committee of the Textile Institute, Manchester, several papers have been presented by experts setting forth the respective merits of various methods, not only of power transmission but of power development. The relative advantages of reciprocating engines, steam turbines, gas engines, oil engines, and electric motors have already been pretty fully set forth, while more recently the long-standing claims of leather belts for subsidiary power transmission have been challenged by the chain drive, and on the 24th ult. another paper was read urging the superiority of steel driving belts to the cotton ropes usually employed for main power transmission. Notwithstanding all that has been said, however, respecting power developments and transmission, no serious innovation has been made upon the methods that have been in vogue during the last 20 years. It is true that a survey of Lancashire mills would reveal a few examples of every method of power development enumerated, but the horizontal reciprocating engine, either triple or compound, with Lancashire boilers and superheaters is so generally adopted that it may be regarded practically as the standard type of power plant, and the cotton rope drive from the engine flywheel to the main line shafts on each floor as the standard method of power transmission. It is counted to the Lancashire millowner for conservatism that he adheres to old and well-tried methods, but, if it be so, it is conservatism of a wide-awake kind, for no power user is more alert to seize an advantage when it has been clearly demonstrated, though his notions on this point are apt to differ from those who are interested in only one feature of his power installation and see only one item in his balance-sheet. He was not slow to take up rope driving and discard his spur gears and second motion and vertical shafts when the

advantages of the former were demonstrated. These, however, did not consist, as some engineers who ought to know better appear to think, in the more regular driving and lesser resistance of ropes as compared with gearing—as a matter of fact, the resistance is more—but in the greater reliability and diminished cost, the former being, however, the determining factor, and one which is too often overlooked by advocates of competitive methods. Spur gearing for a long time reigned supreme, but, with the increase in size of mills and engines, a point was reached at which it became difficult for the teeth of large spur driving wheels, designed on ordinary lines, to transmit the power that was required, and those who can throw their minds back some 20 years will recall the interest and discussion aroused when Mr. Michael Longridge first suggested a radical departure from established practice as regards the form of teeth for spur driving wheels, and to which he briefly alluded in his recent paper on engine breakdowns (see p. 216 ante). The objection to all tooth gearing, however, in main transmissions is that in the event of failure of a few teeth a serious and costly stoppage may be entailed, and this is the event which, of all others, the millowner most dreads, and beside which a slight gain in fuel is a bagatelle. With the adoption of ropes much anxiety on this score was avoided, since a rope could be respliced or renewed with little or no interference with the continuity of running. It is not necessary to labour the question of friction losses between prime mover and machine to establish the claims of ropes over gears. In fact, to make any such claims is erroneous, and the millowner has been quite ready to adopt the rope drive, as we have seen, even though he pays a little more in the way of power. Whether a thin steel band can claim an all-round superiority over a cotton rope is a matter which must be decided to some extent by experience, and this, so far as regards mill driving, is lacking. Steel driving bands are not new. They have been adopted for some time on the Continent for heavy power transmission service, and some interesting claims are made for them, amongst these being the small amount of slipping, the narrow width of a belt for a given power, and the high speed at which they can be run. In his paper before the Textile Institute Mr. Kruger quoted some figures showing distinct improvements in efficiency by the use of steel belts in place of cotton ropes, but, with all due respect to these, they were too limited and too partial to permit of anything like a complete judgment being formed as to their merits. Questions of durability, facility of handling, ease of renewal, apart from those of cost and economy of power, are of importance to the millowner, and until he can receive fuller information regarding these than were vouchsafed in the course of the paper he is not likely to abandon the use of cotton ropes for steel bands, though we do not doubt he would make the exchange without hesitation if he were convinced of its advantage.

SURFACE COMBUSTION.

In the course of a lecture on "Surface Combustion" recently delivered before the Royal Institution, Prof. W. A. Bone stated that by applying the principle of surface combustion to the gas-firing of multitubular boilers it had been possible to obtain results with coal gas corresponding to the transmission of nearly 95 per cent. of the net calorific value of the gas to the water in the boiler. The first experiments in Leeds were made with a single steel tube 3ft. in length and 3in. diam., packed with fragments of granular refractory material, meshed to a proper size, and fitted at one end with a fire-clay plug, through which was bored a circular hole, ¾in. diam., for the admission of the explosive mixture of gas and air at a speed greater than that of back firing. Such a tube is the fundamental unit of the boiler system, because boilers of almost any size may be constructed merely by multiplying the single tube, and as each tube is, so to speak, an independent fire or unit, the efficiency of the whole is that of the single tube, or, in other words, the efficiency of the whole boiler is independent of the number of tubes fired. In experimenting with such a tube, it was found possible to burn completely a mixture of 100 cub. ft. of coal gas plus 550 cub. ft. of air per hour, and to evaporate about 100lbs. of water from and at 100° C. per hour (20lbs. to 22lbs. per square foot of heating surface), the products leaving the further end of the tube at practically 200° C. This meant the transmission to the water of 88 per cent. of the net heat developed by the combustion, and an evaporation per square foot of heating surface nearly twice that of an express locomotive boiler. Of the total evaporation, no less than 70 per cent. occurred over the first linear foot of the tube, 22 per cent. over the second foot, and only 8 per cent. over the last foot. A boiler erected at the Skinningrove Ironworks for use with coke-oven gas consists of a cylindrical drum 10ft. diam. and 4ft. from front to back, traversed by 110 steel tubes, each of 3in. internal diameter, which are packed with fragments of suitable refractory granular material. Trials made with this boiler at the end of July, 1912, after it had been running for five months, showed that of the net heat supplied 92·7 per cent. was utilised, 3 per cent. passing away with the burnt gases, and 4·3 per cent. being lost by radiation, &c., but none in unburnt gas. Deducting the steam equivalent of the power consumed in driving the fan the over-all efficiency of the plant is practically 90 per cent. The Skinningrove Company have put down a second unit for their new battery of coke ovens, and within the last few months the firm of Krupps have installed a boiler in connection with one of their coking plants in the Ruhr district of Westphalia, from the plans of the Skinningrove plant. This boiler has been running successfully since October last, and about three weeks ago underwent its official steam trials, the results of which are understood to confirm those obtained at Skinningrove.

AERIAL ROPEWAYS.

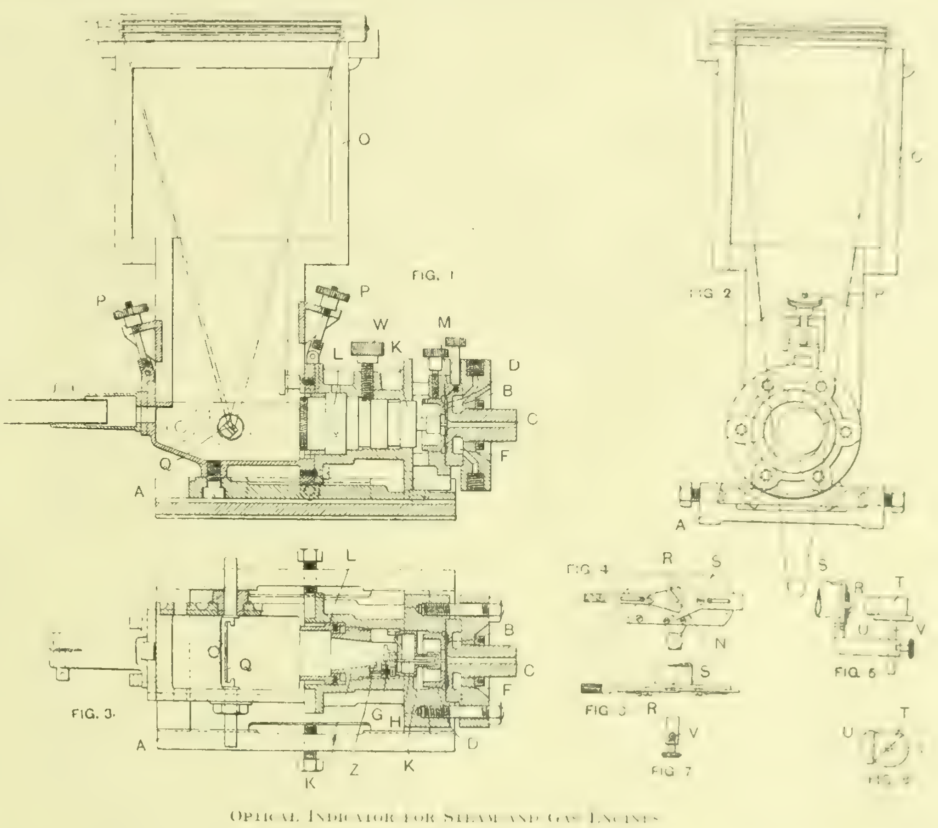
At a meeting of the Birmingham Association of Mechanical Engineers, held on Saturday last, a paper was read by Prof. G. Kapp on the fundamental principles of electric telpherage. He said the idea of conveying goods over an aerial ropeway had been carried into practical application by the Chinese long before the beginning of our civilisation. The first record of such an application in Europe dated back to 1411, and was contained in a manuscript in the Vienna Library. The Dutch engineer Wybe was, however, generally credited with the invention of aerial ropeways, since he built several about the year 1644 in the neighbourhood of Dantzig for the conveyance of clay over water-courses. Since in those early days no other but hempen ropes were available, the span and carrying capacity of these ropeways was necessarily limited, and it was only after the invention of the wire rope that this method of transport could attain some importance. This brings them to the year 1834, when wire rope telpherage was first used in connection with the metal mines in the Harz Mountains. The general principle had remained the same; namely a fixed rope on which the load was suspended from rollers, and a tow-rope in motion for pulling it along. The suppression of the tow-rope and the substitution for it of an electric motor was the invention of the late Prof. Fleeming-Jenkin, who also coined the word "telpherage," meaning the carrying of something over a long distance. In the working out of his invention Prof. Fleeming-Jenkin became associated with Profs. Ayrton and Perry, and the result of this co-operation was the erection of the electric telpher line at Glyn on the estate of Lord Hampden for the conveyance of clay from a brickfield. This had been the first electric telpher line anywhere in the world, and it had been perfectly successful, both technically and commercially.

OPTICAL INDICATOR FOR STEAM AND GAS ENGINES.

THE apparatus shown in the accompanying cuts has been designed and patented by Prof. W. E. Dalby, of the City and Guilds Engineering College, London, S.W., and William Watson, Assistant Professor of Physics, of the Imperial College of Science and Technology, South Kensington, London, S.W., for recording fluid pressure variations, and is particularly adapted to obtaining indicator diagrams from high-speed engines, such as internal combustion engines. The indicator is of the type comprising a pair of mirrors, one of which is rotated about its axis by the movement of a diaphragm under the action of the fluid pressure, while the other is rotated about an axis at right angles to the former axis by a reciprocating part of the engine, records of the various fluid pressures being made upon a photographic plate, by means of a ray after reflection from both mirrors. In the arrangement under notice the necessary adjustment of the line corresponding to atmospheric pressure when the diaphragm is changed is effected by altering the position of the mirror, the position of the diaphragm being unaltered. There is also provided an adjustable stop at the back of the diaphragm, and means whereby accumulation of liquid in contact with the diaphragm is prevented. Any existing source of light can be made use of for obtaining a photographic record of the diagram.

Referring to the illustrations, Fig. 1 is a sectional elevation of the apparatus, Fig. 2 is an end elevation, Fig. 3 is a sectional plan; while Figs. 4, 5, 6, 7, and 8 are detail views, showing devices for obtaining a suitable source of light for the production of the diagram. The whole of the indicating apparatus is mounted on a rigid baseplate A adapted to be securely fixed to the engine. The diaphragm B is placed in communication with the engine cylinder through the pipe C, and a stop D, adjustable by screwing relatively to the framework A, is provided at the back of the diaphragm, the stop being adapted to bear against the diaphragm along the circumference of a circle, and to be fixed in any given position by means of a set-screw. A water-cooling chamber F is provided in the neighbourhood of the diaphragm. The diaphragm is connected to the pivoted mirror G by means of a rod H, and in order to alter the adjustment of the line corresponding to a given pressure, such as atmospheric pressure, the mirror is moved relatively to the diaphragm by rotating the piece K by means of a tommy bar inserted into one of the apertures L. This piece K carries the mirror G, and its movement in the longitudinal direction relative to the rod H, which is held steady by the diaphragm, causes the mirror to tilt to give the necessary adjustment. A drain hole M is provided in the space in front of the diaphragm, this hole being normally closed by means of a screw which can be removed in order to remove oil or other liquid from the front of the diaphragm. The camera O is mounted on the apparatus so that it can be readily removed by loosening the catch screws P. A pivoted mirror Q is provided, actuated in any suitable manner from the piston of the engine, and in any desired phase relationship with the movement of the piston. The source of light may be any suitable existing source, and an image, for instance, of an electric arc may be obtained on one of the apertures N of the diaphragm plate S, by means of a prism T and lens U, mounted so as to be capable of rotation on the spindle V. The aperture R may be varied as desired by means of a pivoted plate, carrying apertures, any one of which may be placed in the operative position. A fixed concave mirror Z may be provided in the neighbourhood of the mirror G, in order to give a datum line at any determined distance from the atmospheric line. The diaphragm plate S is carried by a tubular plate, and carries the holder for the lens and mirror T U.

The operation of the apparatus is as follows. The lens and mirror T U are adjusted so as to give an image of the source of light on one of the apertures R. This image is focussed by means of the concave mirror G, and the plane mirror Q, on to the ground glass of the camera, which can be replaced in the usual manner by a sensitive plate. The mirror Q is given a movement corresponding with the movement of the piston of the engine by any suitable means, the driving mechanism of the mirror including an epicyclic device, whereby the phase can be altered to give any desired difference of phase between the movement of the mirror and the movement of the piston of the engine. A diaphragm suitable to the pressures to be recorded is fitted into the apparatus and the position of the mirror G adjusted by rotating the piece K, by means of a tommy bar inserted in one of the apertures L. The pressure in the cylinder acts on the front of the diaphragm B causing this to tilt the mirror G in such a manner as to cause a spot of light to move on the ground glass or sensitive plate in the direction at right angles to the paper, Fig. 1. The motion of the mirror Q imparted from the engine piston or other reciprocating part of the engine causes



OPTICAL INDICATOR FOR STEAM AND GAS ENGINES.

the spot of light to move over the ground glass or sensitive plate in the direction parallel to the paper. It will thus be seen that the pressure diagram is produced on the ground glass or on the plate, corresponding with the pressures in the cylinder at different points of the stroke of the piston of the engine. In order to keep the diaphragm cool, water may be supplied continuously through the chamber F, and if any condensation takes place in the front of the diaphragm, the condensed liquid can be removed through the aperture M by removing the screw. It will be seen that in order to remove the mirror it is only necessary to remove the camera O and withdraw the piece K outwards after the screw W has been slackened. The part K, being withdrawn to the left (see Figs. 1 and 3), carries with it the mirror and the rod H, leaving the diaphragm in position so that there is no need to stop the engine to remove the mirror.

Institution of Electrical Engineers: Manchester Local Section.—The next meeting will be held at Liverpool University on Tuesday, March 24th, when Mr. F. J. Teago will read a paper entitled "Experiments on Air Blast Cooling of Transformers." The equipment and apparatus for air measurement used in the experiments described in the paper will be in operation.

CENTRALISED ELECTRICAL CONTROL SYSTEM FOR PANAMA CANAL LOCKS.

THE electrical specification, design, and manufacture of the Panama Canal centralised control system may properly be regarded as one of those undertakings which, from an

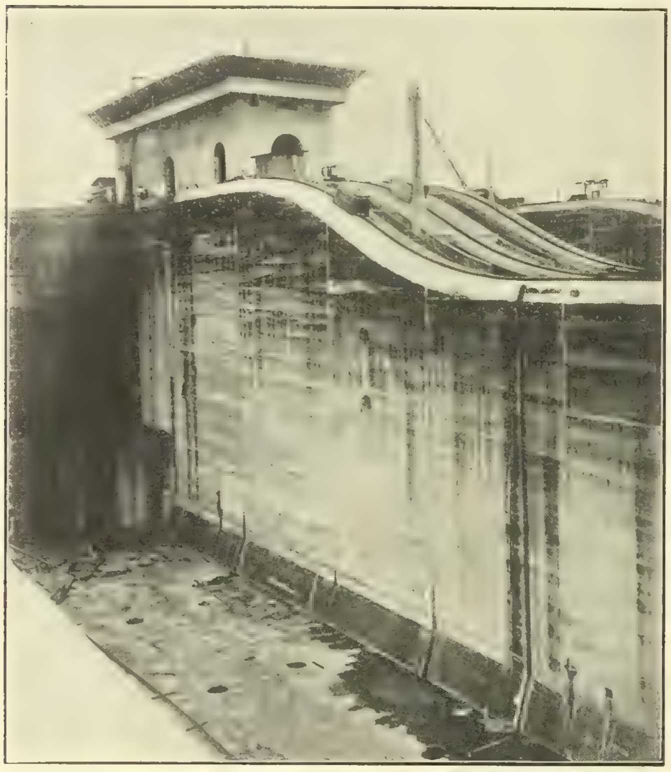


FIG. 1.—CONTROL HOUSE. CENTRE WALL OF UPPER LOCKS AT GATUN, SHOWING TOWING TRACKS.

engineering standpoint, not only arouses a lively interest, but also presents an opportunity for much valuable instruction. The interest results mainly from the immensity of the canal project itself, and the instruction from a consideration of the methods employed to ensure the passage of even the largest ships afloat across the Isthmus with speed and safety. The complete operation of the canal locks, terminals, and auxiliary equipment utilises electrical energy throughout, with the present exception of the Panama Railroad, the electrification of which is under contemplation. The specifications for the entire generating, lock-controlling, and distribution system for operating the Panama Canal were prepared under the supervision of Mr. Edward Schildhauer, electrical and mechanical engineer, Isthmian Canal Commission.

Generation and Distribution.—The power system for the operation of the locks, towing locomotives, lights for the locks and buildings, and motors not directly connected with the lock control comprises a 7,500 kva., 2,200 volt hydro-electric power plant at the Gatun Dam; a 4,500 kva., 2,200 volt Curtis turbo-generator electric power plant at Miraflores for emergency, lately used to supply power for construction work; a double 44,000-volt transmission line across the Isthmus, connecting Cristobal and Balboa with the two power plants, four 44,000-2,200 volt sub-stations, stepping down at Cristobal and Balboa, and up or down at Gatun and Miraflores, depending on which of the two plants is supplying power; 36 2,200-240 volt transmission stations for power, traction, and light, at Gatun, Pedro Miguel, and Miraflores locks; three 2,200-220-110 volt transformer stations for the control boards at the locks; stations at Cristobal and Balboa for coal-handling plants, machine shops, and dry docks.

The system of connection throughout employs a double-bus, double-switch scheme, with provision for disconnecting any oil switch for cleaning or repairs without interrupting the circuit. In the power-house and the four 44,000-2,200 volt sub-stations, the oil switches are solenoid operated, and in the 36 transformer stations hand operated. All 2,200-volt oil switches have disconnecting switches, so arranged that live parts are completely covered.

For the hand-operated switches a pipe framework supports vertical metal guides which carry the oil switch operating mechanism and slate base forming a section of the switchboard panel. On the guides a lever and toggle mechanism is mounted, by which the oil switch and slate base may be raised and lowered. Above the oil switch, and mounted on the pipe framework, a stationary cast-iron base carries the disconnecting switch studs and insulators. The high tension leads run to the tops of the disconnecting switch studs, and the bottom of each stud is equipped with contact fingers. On the top of each oil switch stud is mounted a contact blade. When the oil switch is raised, these blades engage the contacts on the bottom of the disconnecting switch studs, which thus in the closed position form extensions of the oil switch studs. When the oil switch is lowered it is completely isolated from the circuit. When the oil switch is raised it always goes to a fixed height, where it is latched. An interlock prevents the oil switch from being raised or lowered unless its contacts are open, precluding the circuit being closed or opened by the disconnecting switch. In some instances another interlock makes two single-throw switches a double-throw switch, and prevents both switches being closed at the same time.

For solenoid-operated switches, the same form of disconnecting switch is used; but the solenoid is stationary and the connecting mechanism to the oil switch has a vertical slotted link which allows the oil switch to be raised and lowered without being disconnected from the solenoid

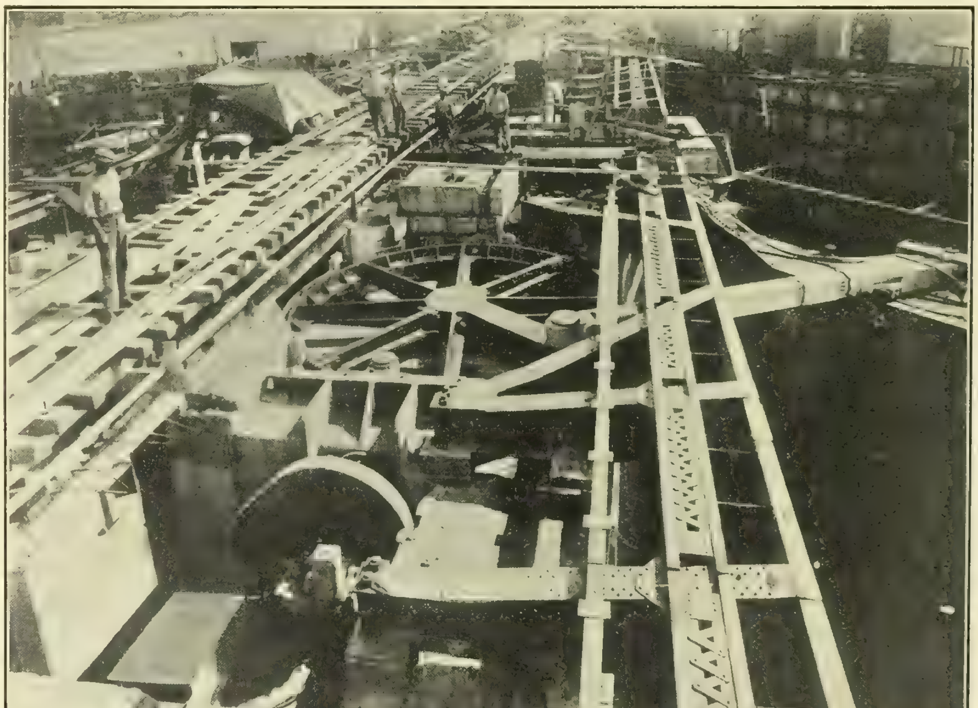


FIG. 2.—MITRE GATE MOVING MACHINE, GATUN UPPER LOCKS.

mechanism. A mechanical interlock prevents the raising or lowering of an oil switch while in the closed position.

The instrument and control board for the Gatun generat-

ing station is totally enclosed. The switchboards for the transmission line sub-stations are of the vertical type, with control apparatus and mimic connections symmetrically arranged on the middle section of the panels.

Power Supply and Control Panels for Lock Machinery Motors.—Current for the lock machinery and towing locomotives is transformed from the 2,200-volt system in the immediate vicinity of where it is used. There are a total of

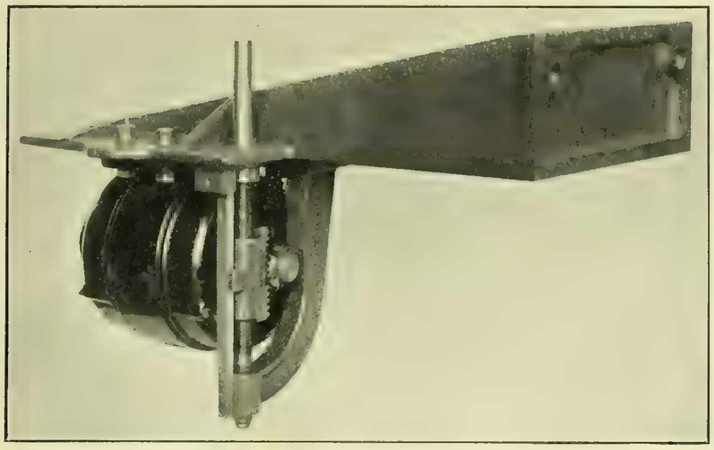


FIG. 3 – MITRE GATE TRANSMITTER MACHINE WITH COVER REMOVED.

36 transformer stations, for all locks, each containing duplicate 200 kva. three-phase 2,200-240 volt transformers for power, and one single-phase 25 kva. 2,200-220-110 volt transformer for lighting. The stations, normally fed from the 2,200-volt buses in the 44,000-2,200 volt sub-stations, can also be operated from the power plants; the stations at Gatun locks from the Gatun hydro-electric station; and the stations at Miraflores and Pedro Miguel from the Miraflores emergency steam plant. To give an idea of the number and sizes of motors to be controlled in operating the lock machinery the following table is interesting:—

Machines and operation.	Motors each machine and hp.	Number of motors.				Total horse-power.
		Gatun.	Ped.M.	Mira.	Tot.	
Mitre gate, moving, each leaf	1–25	40	24	28	92	2,300
Mitre gate, mitre forcing	1–7	20	12	14	46	322
Fender chain, main pump	1–70	16	16	16	48	3,360
Fender chain, operating valve	1 1–2	16	16	16	48	24
Rising stem gate valve	1–40	56	24	36	116	4,640
Cylindrical valve	1–7	60	20	40	120	840
Guard valve	1–25	6	6	6	18	450
Auxiliary culvert valve	1–7	4	4	4	12	84
Totals	--	218	122	160	500	12,020

There are many motors not included in the above table, as, for instance, those for the spillway gates, for the hand rails on the mitreing gates and for the sump pumps. The spillway gates are remote controlled from a special control board, and the control of the hand-rail motors is given in connection with the discussion of mitreing gates. The motors are started and controlled by contactor panels located near them, the contactors of which handle the main motor currents. These contactors are controlled from the central control house. The smaller motors, including those for cylindrical valves, auxiliary culvert valves, and mitre forcing, are started by being thrown directly on the line. Two double-pole contactors are used, one for forward and one for reverse. In the case of larger motors for mitre gate moving, rising stem valves, and guard valves, a starting point with resistance in two legs of the three-phase circuit is provided.

In all cases the contactors are operated from the control boards by three wires, one for forward, one for reverse, and a common return. In the case of panels having a starting point, the period during which the motor remains on the resistance is automatically controlled by a dashpot, so that the starting operation at the control house is the same, simply energising a forward or reverse wire as the case may be. The control connections are arranged in such manner that each individual machine may be controlled locally.

Location and Operation of Lock Machinery.—From an operating standpoint the machinery was placed below the coping of the lock walls, thus affording a clear space for manœuvring ships and protecting the apparatus from the weather without erecting numerous houses. The mitreing gates consist of two massive leaves pivoted on the lock walls which operate independently of each other. A pair of gates is located where each change of level occurs and divides the locks into 1,000ft. chambers. In addition to these gates, at lake and ocean ends are duplicate pairs of gates used as guard gates. To handle the vessels of various sizes with the minimum use of water, mitreing gates of the same description as those above are installed, dividing 1,000ft. locks into two compartments. These gates are termed intermediate mitreing gates. When the mitreing gates are closed they are what might be termed clamped in this position by a device called a mitre-forcing machine.

On the top of all mitreing gates a foot walk with hand rails is provided. When the gates are opened and in the recesses provided for them in the lock walls, these hand rails would interfere with the passing of the towing locomotives, except in the case of the lower guard gates. The hand rails are therefore made to be raised and lowered. This is done by a motor under the foot walk, controlled from the lock wall. Near the approach to each foot walk a controller is located in the lock wall flush with the surface, this controller being operated by a foot push.

The chain fenders are stretched across the canal in front of all mitreing gates, which can be exposed to the upper lock level and also in front of the guard gates at the lower end. These chains are maintained in a taut position when the gates behind are closed, and are lowered when the gates are opened for the passage of a ship. The chains are raised and lowered by a method similar to that followed in hydraulic elevators, with the additional feature that if a ship approaches the gates at a dangerous speed, and rams into the chain, the chain is paid out in such a way as to gradually stop the ship before it reaches the gates. Lowering the chain for the passage of a vessel and raising it again after the vessel has passed is accomplished by two motors, one driving the main pump supplying water under pressure, and the other operating a valve which controls the direction of movement of the chain.



FIG. 4 MITRE GATE INDEX.

These two operations are combined in one, each motor being stopped automatically by a limit switch when the motor has performed its function.

The filling and emptying of the locks is accomplished by three culverts, one in the middle wall and one in each side wall, the flow of water being controlled by rising stem valves. They are located in the culverts at points opposite each end of each lock, so that the culvert can be shut off at any desired point for filling a lock with water from above, or up stream.

or for emptying it by allowing it to flow out and down to the next lock. Lateral culverts conduct the water from the main culverts, under the lock chambers, and up through openings in the lock floors. The rising stem valves are installed in pairs, and each pair is in duplicate; also each culvert is divided into two parallel halves at these valves by a vertical wall. This arrangement reduces the size of each valve and makes it more easily operated, each valve being 8ft. by 18ft.

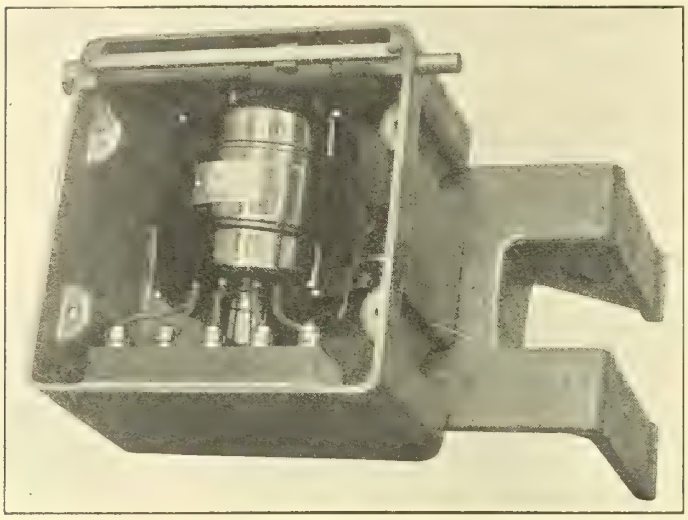


FIG. 5.—CHAIN FENDER TRANSMITTER MACHINE, COVER REMOVED.

One pair of duplicates is left open as a guard, or reserve pair; the other pair is used for operating, so that in case of an obstruction in the culvert or accident to the machinery the duplicate pair can be used.

At the upper ends of the culverts at the side walls the duplication is accomplished by three valves in parallel, called the guard valves. They perform service exactly similar to the rising stem valves, except that three valves in parallel in this case must conform to the same laws as the two in parallel in the other case. The culvert in the middle wall must serve the locks on both sides, and to control this feature cylindrical valves are placed in the lateral culverts that branch out on each side. There are ten of these on each side of the culvert at each lock. At the upper end of each set of locks there are two valves in the side wall for regulating the height of water between the upper gate and upper guard gate, as it is desired to maintain the level of the water between these gates at an elevation intermediate between that of the lake above and that of the upper lock when the upper lock is not at the same level as the lake. These valves are called the auxiliary culvert valves.

Centralised Control and Indicating System.—As the flight of locks at Gatun, for instance, extends over approximately 6,200ft., and the principal operating machines are distributed over a distance of about 4,000ft., central mechanical transmission of control of machines would be almost impossible; and to control the machines locally would mean a large operating force distributed practically along the full length of the locks. Such a force would be difficult to co-ordinate into an efficient operating system. The situation, therefore, resolved itself into centralised electrical control, which reduces the number of operators, operating expense, and liability to accident. To accomplish this system of control, a control board for each lock was constructed which permitted having all control switches located thereon mechanically interlocked, so as to minimise the errors of human manipulations.

The control boards are installed in control houses located on the middle walls at points which afford the best view of the locks. They are made approximately operating miniatures of the locks themselves, and are arranged with indicating devices which will always show the position of valves, lock gates, chains, and water levels in the various lock chambers; and, with the exception of such machinery as needs only an "open" or "closed" indication, the indications will be synchronous with the movement of the lock machinery.

A complete synchronous indicator consists of a transmitter located at and operated by the machine in the lock wall, and a receiver operating an indicator at the switchboard in the control house. Both transmitter and receiver have a stationary and a rotating part. The stators have three-phase windings with leads from three corresponding equidistant points brought out and connected together, but not connected to a source of power, the stator coils being energised by induction from the rotors. The rotors are bi-polar, and are connected in multiple and energised from a 110-volt, 25-cycle single-phase source.

The movement of the lock machinery, and with it the connected transmitter rotor, produces a field in the transmitter stator polarised in the direction of the rotor axis, which induces voltage in the stator coils. This voltage is transmitted by the three-phase connection above mentioned to the receiver stator coils and duplicates in them, but in the reverse direction, the same conditions of polarity and voltage as present in the transmitter. The rotor of the receiver being energised by the external source in the same direction as that of the transmitter, is reacted upon by the polarised receiver stator until the magnetic axes coincide and the rotors of both transmitter and receiver are in the same relative position. Any difference in the position of the transmitter and receiver rotors causes a difference of potential between the stator windings with a consequent flow of current and resultant torque, which again moves the receiver rotor to the same relative position as that of the transmitter rotor. The receiver rotor follows closely and smoothly the movement of the transmitter rotor, and consequently imparts to the position indicator a movement identical with the movement of the lock machine, although on a scale reduced to the requirements of the control board. A brief description of the individual synchronous indicators follows.

In the case of the mitreing gates, the vertical operating shaft is connected to a shaft which operates the transmitter machine. The latter shaft is threaded and carries a nut on which is mounted a rack. The rack engages a gear on the rotor shaft, and this turns the rotor as the gates operate. The mitreing gate indicator comprises a pair of aluminium leaves, shaped to correspond to the plan view of the top of the gate, which travel horizontally just above the top of the board, the hinge ends being connected to shafts extending down through the surface of the board, where they are geared to the receivers by means of bevel gears. When the miniature gates are completely opened they are covered by shields, to give the effect of the gates folding back into recesses in the lock walls.

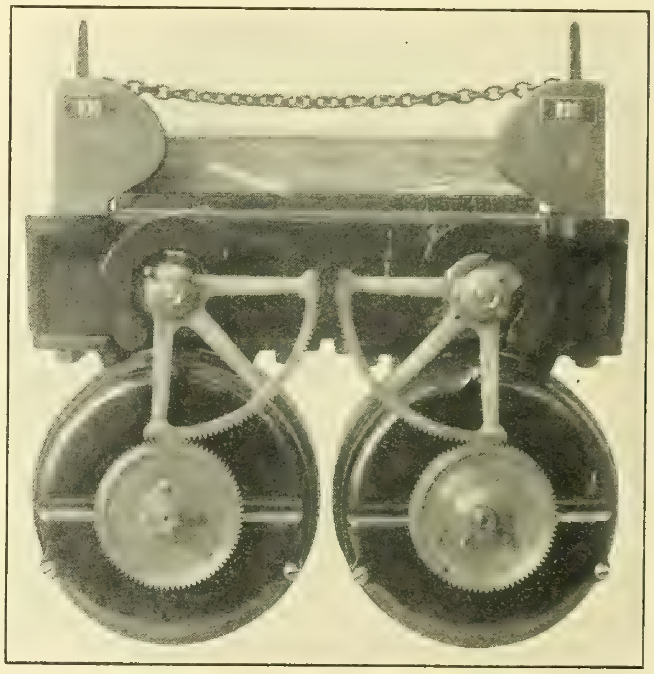


FIG. 6.—CHAIN FENDER INDEX.

For the chain fender the position indicator transmitter is driven by the shaft which operates the limit switch that controls the stroke of the piston. The indication on the

board is given by a small aluminium chain, which, like the large chain, is raised and lowered, each end operating independently, the large chain being lowered to the bottom of the lock and the small chain into a slot on the control board. The ends of the miniature chain are fastened to semaphore arms which are connected to segmental gears meshing with the driving gears on the receiver machines. As the receiver rotors turn the chain is either lifted or lowered, the position

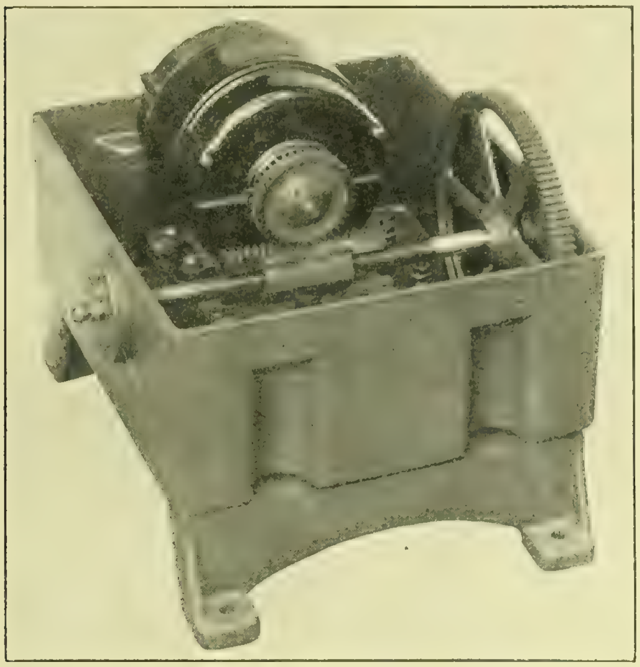


FIG. 7. STONEY GATE VALVE TRANSMITTER MACHINE, COVER REMOVED.

of the large chain from the bottom of the lock being indicated by the angle of the semaphore arms.

As the rising stem valves occur in pairs, their position-indicator machines occur in pairs also. The transmitter rotor is driven by a shaft and gearing similar to that described for the mitreing gates. Each indicator is similar to a small elevator, a car being used to indicate the position of the valve gate. Both front and back of the shaft is fitted with opal glass marked with black lines for the quarter, half, and three-quarter positions. A small aluminium cage moves up and down in each compartment. A drum for operating the cord which raises and lowers the cage is located underneath the control board, and is operated by the receiver through a suitable train of gears. To make the indications visible from points up and down the control board, the elevator shaft under each car is always illuminated and the portion above is dark.

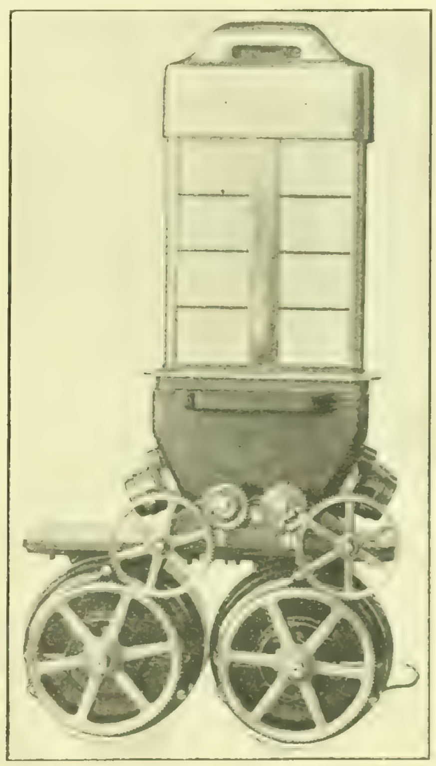
Water Level Indicators.—The specifications covering the water level indication required an accuracy of one-twentieth of a foot or one-tenth of 1 per cent. in actual water level. The required accuracy was obtained by two sets of transmitters and receivers, one set connected to a fine index in which the rotors make ten complete revolutions, and the other set connected to a coarse index operating less than 180°. The fine index is a hollow cylinder carrying a pointer, the length of the cylinder being such that when an aluminium ball representing the coarse index, which can be depended upon for coarse indication, is within the limits of the cylinder, the reading of the fine index is correct within the limits specified. The scales are illuminated by lamps.

For water-level indication, wells 36in. square in the lock walls, with communication to the lock by a small opening at the bottom of the well to dampen surges, contain a welded steel box float, 30in. square by 9in. deep. A non-slipping phosphor-bronze belt transmits the movement of the float to a sheave fitted with pins on the transmitter mechanism, the pins registering with holes punched in the belt. The sheave shaft is carried in ball bearings with oil cups for lubrication and drainage cocks at the bottom of the bearings. The position of the mitre forcing machine is not indicated by synchronous indicators, but its open and closed positions are shown by red and green lights and a mechanical indicator on the control board representing the machine.

Control Boards.—The control boards are of the flat top benchboard type, 32in. high by 54in. wide, built in sections, with total lengths as follows: Gatun, 64ft.; Pedro Miguel, 36ft.; Miraflores, 52ft. The side and centre walls of the locks are represented by cast-iron plates and the water in the locks by blue Vermont marble slabs. The control board is supported by a wrought-iron framework resting on base castings, which are in turn supported on the operating floor of the control house. The control switch handles are mounted above the surface of the board and operate through an angle of 90°. They are provided with name plates for the "open," "closed," and "off" positions. The space immediately below the flat top of the control board is occupied by the contact fingers of the control switches, mounted on the operating shaft, synchronous receivers, and their cable connections. Connection boards are provided for the cables, which are led up from each side, as are buses for supplying current to the control switches, receivers, and the lamps that illuminate the scales of indicators. The receivers, transmitters, and lamps are operated at 110 volts, while the control circuits are 220 volts, both using 25-cycle alternating current.

Mechanical Interlocking System.—In order to make it necessary for the operator to manœuvre the control switch handles always in a certain order, corresponding to a predetermined sequence of operation of the lock machinery, and to prevent the operator in control of one channel from interfering with the machinery under the jurisdiction of the operator controlling the other channel, these control switches are provided with interlocks. The interlocks are in two vertical racks under each edge of the board and some distance below, so that they may be inspected and oiled.

Vertical shafts operated by connecting rods from the control switch shafts extend downward past the electrical parts for the operation of the interlocks. The interlock system



[illegible]

is essentially a bell-crank mechanism, connecting the shaft of the control switch through a movable horizontal bar to a vertical operating shaft, which can or can not move, according to the relative positions of the interlocking bars and dogs. The interlocking rack is a steel frame carrying five horizontal members. Upon these, and tying them together, are vertical steel straps which carry brass runway posts for the vertical

and horizontal interlock bars. These posts are riveted to the vertical steel straps. Forked cranks mounted on the vertical operating shafts move the horizontal interlock bars by means of pivot blocks set over pin blocks riveted to the horizontal bar. The interlock bars and dogs are shaped so as to keep the dogs in line with the axis of the bars when under pressure by being engaged with another dog on a vertical bar. Every control switch uses a horizontal bar of from 3ft. to 50ft. long. The interlock system depends mainly on the action of engaging bevel dogs located on horizontal and vertical bars, the movement of a horizontal bar tending to lift a vertical bar by bevels on the dogs. A horizontal bar cannot be moved without raising a vertical bar. Thus if at any time a dog on a horizontal bar rests against the upper end of a dog on a vertical bar, no movement of the horizontal bar where the dog engages with the vertical bar can take place, and the control handle connected to that particular horizontal bar is locked.

Interlocks prevent the chain fender from being lowered until adjacent mitreing gates have been opened, and also prevent the gates being opened until the chain is in the raised position. In this way it is assured that the chain fender will always be in the up position to protect the gate when the gate is closed. To avoid unnecessary complication, each end of the chain is interlocked with the leaf on its side of the lock only, because as a rule both leaves of a gate, as well as both ends of a fender chain, will be opened simultaneously, and further interlocking is unnecessary. After the mitreing gates are closed, a mitre-forcing machine is operated by a control handle and locks the ends of the gates closed. This machine cannot be operated until the gates are closed.

Also the rising stem valves of the side wall, next above or below a mitre gate, must be closed while the mitre-forcing machine is open. As the mitre-forcing machine cannot be closed until the gates are closed, this means that the valves either above or below the gate must remain closed until the gate itself is closed, thus preventing the operator from creating a current of water around the gates while they are open or being moved in opening or closing. This interlock is not included on the middle wall valves for the reason that they will be used with the locks on either side and must be free for that purpose.

Either pair of rising stem valves may be opened first, at the choice of the operator, an interlock becoming effective when the first valve of the second pair of duplicates is opened. This is done by a novel arrangement of equalising levers acting against the ends of the interlock bars, with certain definite amount of lost motion which is taken up on opening the first pair of valves, thus putting the interlocks in operation on the next pair. To illustrate this operation consider, for example, a side wall culvert at Gatun with its principal rising stem valves at each change of level from one lock to the next. The control of these valves is interlocked so that if the valves are opened at one particular point the valves a lock length upstream or downstream cannot be opened. Thus the operator is limited to equalising the water between locks, and cannot allow water to flow from the upper lock past the middle lock into the lower lock, which operation, if permitted, might flood the lower lock walls and the machinery chambers in them. The cylindrical valves are interlocked so that if those on one side are opened the ones on the other side are locked closed, and the opening of one switch on a side will lock the opposite ten. This prevents careless cross-filling between locks, which operation might be combined with the regular method and produce flooding. However, there may be times when it is desirable to employ cross-filling to economise in the use of water from Lake Gatun in the dry season. For this reason this interlock is made removable by the use of a Yale lock and key. In the use of the middle wall culvert, the cylindrical valves on one side or the other must be opened before the rising stem valves can be opened, and the rising stem valves must be closed first. This interlock is applied in order to require the operator to control the flow of water by means of the rising stem valves rather than by the cylindrical valves.

In most cases the locks are divided into two unequal parts by the intermediate mitreing gates. This arrangement makes it necessary to divide the ten cylindrical valves into two groups of seven and three, respectively, for the long and short lengths. A selecting lever is provided for these interlocks, and may be set as indicated by a name plate on the lever to "three," "seven," or "ten" respectively, whereupon the corresponding valves are subject to that interlock

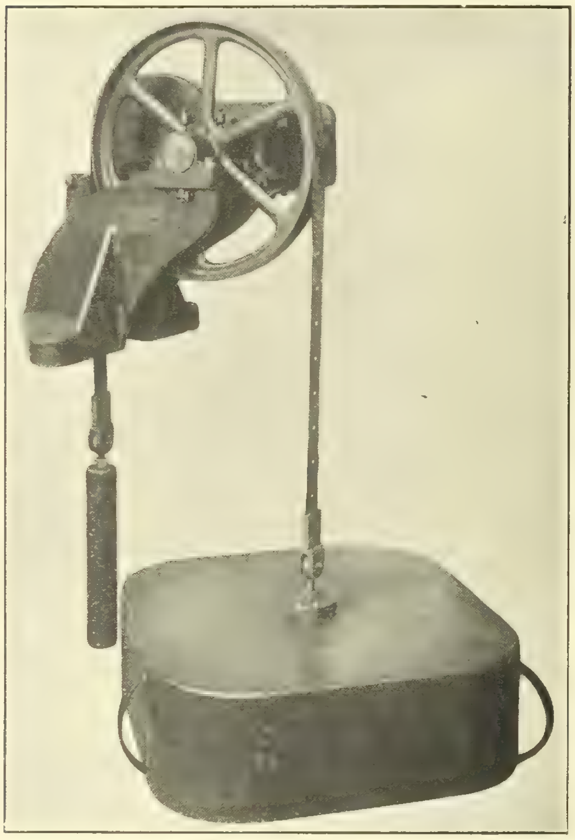


Fig. 9.—Floatwell Transmitter Machine with Float, Weight, and Belt.

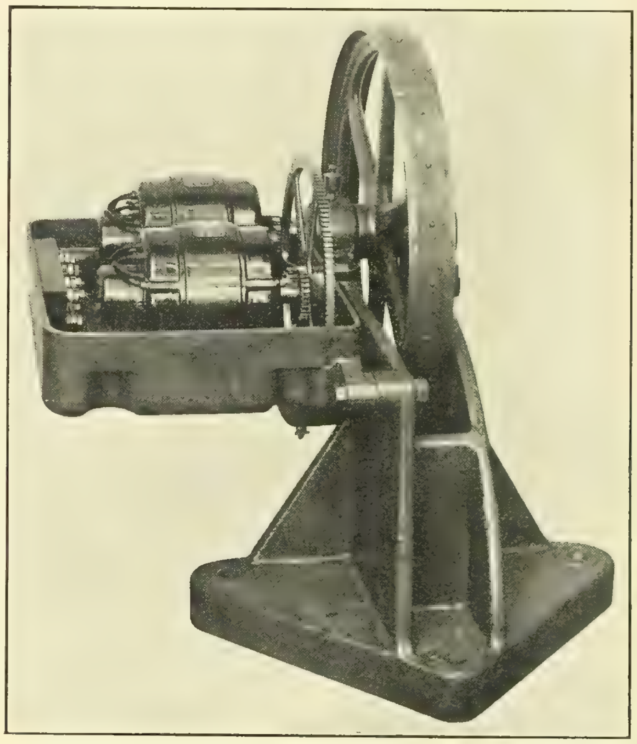


Fig. 10. Floatwell Transmitter Machine, Cover Removed.

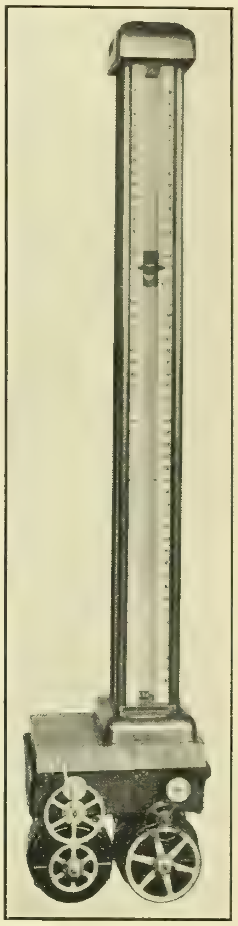


Fig. 11.—Fifty-foot Floatwell Index.

and the others of the group of ten are locked closed if three or seven only are to be used. The failure of the operator to make his selection properly in advance will simply cause him the trouble of going back and doing so, as the remaining valves are locked closed. This arrangement permits handling small vessels without causing waste of water due to operating such vessels in the large chambers. If a short vessel were being passed downstream it would first pass into the chamber having three cylindrical valves. The group selective lever would then be placed on the "three" position, which would permit the opening of three valves above the intermediate gate, but would lock closed the other seven valves above it. After the vessel has been passed below the gate the handle may be reversed releasing the lever and locking three switches.

There are intermediate rising stem valves in the side walls at each intermediate gate, but no interlocks are applied to these, for the reason that they will be used in a more or less irregular manner. Moreover, they control the water only between different sections of the same lock, and there is not the danger from mistakes in operation which exists in the case of the other valves which control water between lock levels. The same is true of the small auxiliary culvert valves, by means of which the space between the upper guard gate and upper main gate is filled and emptied.

In case a large vessel is to be locked through, the interlocks on the intermediate gates can be made ineffective by the operation of a Yale lock, which uncouples a clutch and disconnects the central switch from the operating mechanism. Turning the key removes the interlock and permits the intermediate gates to be thrown open to obtain a 1,000ft. level and the valves operated independently of these gates.

To obviate the possibility of flooding the locks when valves are in a certain position, diagonal interlocking is introduced between the rising stem valves of the side wall and those of the middle wall a lock length away. This interlocking between valves diagonally across a lock when the cylindrical valves are open is needed to prevent the flow of water from, say, the upper lock by way of a side wall culvert to the middle lock, thence by way of the middle wall culvert to the lower lock, thus allowing an operator through carelessness to flood the lower lock walls. If the cylindrical valves of a certain lock are closed, the interlock is not needed on the rising stem valves of that lock; and since such interlock would interfere with the proper use of the valves of its twin lock on the other side of the middle wall, this interlock is automatically removed when all ten cylindrical valves are closed on the particular lock in question, and is automatically applied again if one or more of the ten cylindrical valves are opened. Furthermore, the valves of the side wall immediately at the gate which is being moved will be open to equalise water level, and diagonal interlocking will prevent the opening of the middle wall valves a lock length above or below the gate being moved. Each of the four valves of such a group has independent control, their control switches being so interlocked that either pair may be opened and left open as guard valves, the interlocks becoming effective when the operator tries to open the first valve of the second pair. In addition to these pairs of valves in parallel, each pair is duplicated at each change of level from one lock to the next.

All of the lock machinery motors, control panels, centralised control boards, power station generating apparatus, switchboards, transmission line sub-station equipments, coaling stations, and practically the entire electrical equipment for the wharf terminal cranes and for the extensive permanent repair machine shops were manufactured by the General Electric Company, of New York, U.S.A.

SPEEDS AND FEEDS FOR COLD SAWING MACHINES.

THE selection of speeds and feeds for cold sawing is one of the many phases of machine-shop practice which cannot be regulated by fixed rules. The design and construction of the machine and saw, as well as the grade of material to be cut, cause wide variations in both speed and feed. The average output or number of pieces cut for each grinding of the saw is another factor to be considered. Some instructive information on the subject is given in an article in our American contemporary "Machinery" which we reproduce as follows.

One prominent manufacturer of cold saw cutting-off machines states that for sawing 0·30 carbon open-hearth machine steel bars 5in. diam., a feed of 1in. per minute and a peripheral speed for the saw of approximately 45ft. per minute would be used. This speed and feed is regarded as economical when using the vanadium steel high-carbon blades. As an example of this rate of cutting, 1,600 pieces were sawed off in one machine with an average output of 115 pieces for one grinding of the saw. For some classes of work a feed of 2in. per minute and a speed of about 45ft. is employed, but under average shop conditions a feed of ¾in. per minute is considered conservative when cutting 0·30 carbon open-hearth steel with a saw that is in good condition.

When selecting speeds and feeds, it is important to consider the output for one sharpening of the saw. In one shop 200 pieces of special analysis steel and 800 pieces of open-hearth steel (varying from 3¾in. to 4¼in. diam.) were cut at one grinding of the saw. While it may be feasible to cut various grades of steel at the rate of 1,000 pieces with one grinding of a high-speed steel saw, the experience of the company referred to is that on high-carbon tool steel and special alloy steel, such as chrome-nickel, &c., the best economy in grinding the saw will be obtained by using a feed of about ½in. per minute with a surface speed for the saw of approximately 30ft. per minute. When using the speed and feed mentioned, if the saw averages 100 pieces per grinding the output is considered satisfactory. It has been found that some of the special analysis steels cut quite freely, as, for example, 3½ per cent. nickel steel which is sawed as easily as open-hearth 0·30 per cent. carbon steel. On the other hand, some of the softer grades of stock, such as open-hearth machine steel having about 0·15 per cent carbon, do not cut as freely as stock with a higher percentage of carbon. This is because the softer steel is inclined to roll up into the throats of the saw teeth, and if too much heat is generated in the cutting the chips will fuse more or less to the teeth. A good deal of this soft stock, in bars 8in. diam., has been cut with a saw speed of 45ft. per minute and a feed of about ⅝in. per minute. This rate of cutting is considered the most economical for the saw when using vanadium high carbon blades. Some grades of chrome-nickel stock seem to cut quite freely, whereas steel of another make is cut with difficulty and, in some instances, the use of a high-speed steel saw is necessary. Moreover, steel of one make may cut quite differently from that of another make, although the analysis in both cases may be the same; consequently, the speed and feed that will prove most economical must finally be determined by actual tests. Of course it will be understood that the size and power of the machine must also be considered. As to phosphor-bronze, some grades can be cut very easily, whereas some of the bronzes used for gears, &c., are very hard to cut and the edge of the saw is inclined to glaze over; hence it is difficult to give even a general idea of the speeds and feeds.

Another well-known manufacturer of cutting-off machines gives the following data on the time for cutting various sizes of steel stock: Eighty-one pieces 3⅝in. diam., 2 hours 27 mins.; 210 pieces 4in. diam., 7 hours 27 mins.; 54 pieces 5in. diam., 2 hours 22 mins.; 57 pieces 6in. diam., 2 hours 58 mins.; 684 pieces varying from 3⅝in. to 6in. diam., 26½ hours. In the last example the smallest number of pieces of the same size was 2 and the largest 210. The feed was 2in. per minute and cutting speed 48ft. The time for cutting 46 pieces of axle steel 7¼in. diam. was 3¼ hours, the feed being 1¾in. per minute. When cutting flat stock 1⅛in. by 9⅛in. several bars were stacked and cut simultaneously, a total of 246 pieces being cut off in 1 hour 37 mins. The material was low-carbon steel, the feed 3⅞in. per minute, and the cutting speed 85ft. per minute.

Still another concern gives time data for various grades of metal: Time for sawing steel forging, 6½in. diam., containing 0·74 carbon, 1·12 manganese, 0·30 nickel, 7½ mins.; tool steel bar 2½in. diam., 4 mins.; tool steel bar 0·50 per cent. carbon, 3½in. diam., 3½ mins.; Krupp chrome-nickel steel bar 4½in. diam., 5 mins.; Krupp chrome-nickel steel bar 6in. diam., 8 mins. to 10 mins.; 6½in. bar, 0·20 per cent. carbon, 5 mins.; 6in. bar, 0·30 per cent. carbon, 4½ mins. to 6 mins.; 8in. bar of high-carbon steel, 13 mins.; 8in. diam. hard bronze ingot, 6 mins.

All these data represent actual practice and are given as a general guide, although it is necessary, of course, to make considerable allowance for the design of the saw as well as the size and power of the machine.

APPLICATION OF SURFACE COMBUSTION TO LOCOMOTIVE BOILERS.

A DESIGN of locomotive boiler in which the system of surface combustion is applied has recently been patented by Mr. C. D. McCourt and The Bonecourt Surface Combustion, Ltd., Parliament Mansions, Victoria Street, Westminster, London. The boiler is shown in the accompanying illustrations, Fig. 1 being a longitudinal section, Figs. 2 and 3 transverse sections, and Fig. 4 a sectional view of one of the burners on an enlarged scale. The combustible is derived from or constituted by an admixture of oil or other liquid fuel and air, which are delivered at suitable pressure by means of pumps

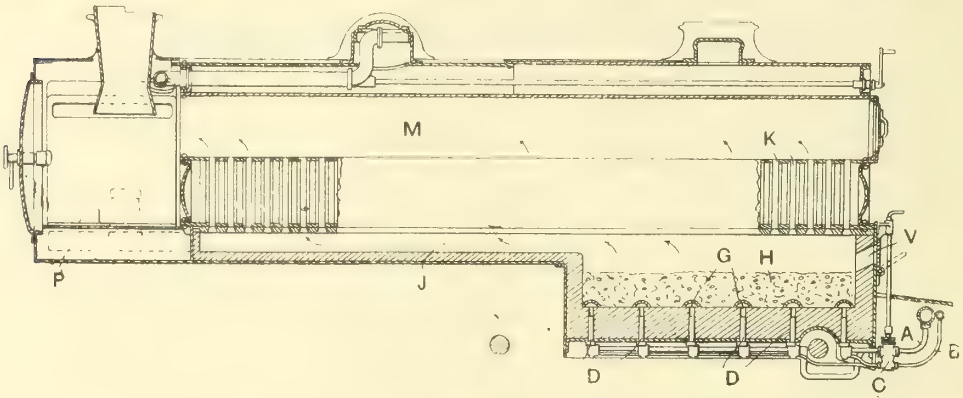
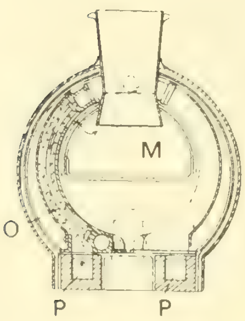
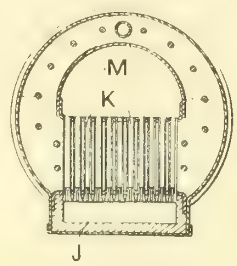


FIG. 1





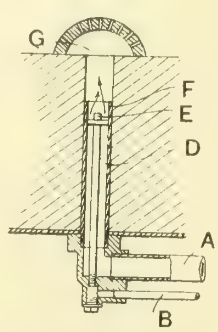


FIG. 2. FIG. 3 FIG. 4.
APPLICATION OF SURFACE COMBUSTION TO A LOCOMOTIVE BOILER.

or blowers to supply pipes B A respectively, and thence through control valves C to a series of burners D, these burners, as shown, comprising a central fuel jet or nozzle E coaxially arranged within an air pipe F and discharging into a mixing chamber G. The oil jet or nozzle E is fitted with a suitable atomising or spraying device, whereby the liquid fuel constituent of the combustible mixture is reduced to a finely-divided form, so as to enable a homogeneous or substantially homogeneous mixture of air and sprayed fuel to be effected within the mixing chambers G. This combustible mixture passes through apertures in the outer or delivery wall of the mixing chamber into a bed H of refractory material in a fragmentary or granular form. As shown, all the burners deliver to a single refractory bed overlying the mixing chambers G.

The hot gases derived from the combustion of the mixture upon or within the bed H (ignition of the mixture being effected by any suitable means, as by the introduction of a flame to the surface of the bed through the ignition door V) pass to a header J extending longitudinally to the boiler shell and thence through a plurality of short tubes K traversing the water space of the boiler to a second header M in communication with the chimney. The tubes K may contain or be packed with refractory material in a granular or fragmentary form, which is raised to incandescence by the hot gases and the heat therefrom transmitted through the conducting walls to the water within the boiler shell. The steam space of the boiler shell communicates with the steam valve or chest through a superheater, which is disposed in the smokebox. The superheater comprises a series of steam pipes O embedded in refractory material in granular or fragmentary form, through which hot gases are led, these gases being taken directly from the header J through the ducts P, which extend longitudinally at each side of the smokebox. The direction of flow of the hot gases through the superheater is opposite to the direction of flow of the steam. In order to start the firing a mixture of any suitable combustible gas and air may be supplied through the air supply pipes, a branch pipe conveying combustible gas being provided for this purpose, the object being that the refractory material in proximity to the air admission apertures may be heated to incandescence before the liquid fuel is admitted.

THE HEAT TREATMENT OF STEEL CASTINGS.

THE Pennsylvania Railroad has for some time been experimenting on the effect of the special heat treatment of steel castings, particularly bolsters and locomotive frames, and the results of these experiments are embodied in a paper presented at a meeting of the American Institute of Mining Engineers at New York on February 18th by C. D. Young, engineer of tests of the railroad, O. A. D. Pease, and C. H. Strand.

In an effort to employ cast steel of a stronger structure than that found in the annealed steel castings, the possibilities of heat treatment which will increase the strength without materially decreasing the ductility may be resorted to. An abstract report (which is a brief outline of what has already been done by the Pennsylvania Railroad Company at its shops and test laboratories at Altoona, Pa.) is of material interest, as it indicates what may be done with steel castings when properly treated, thereby permitting in railway service greater strength of cast-steel parts without any increase in weight or space. The question of the heat treatment of alloy steel castings is not dealt with in this paper. The obscurity formerly surrounding the heat treatment of steel has been for the most part removed by the development of our knowledge of the critical points of steel, pyrometers, furnace construction, and the testing of the finished product. The operations of the heat treatment proper are taken up under the heads of (1) heating for quenching; (2) quenching; (3) drawing.

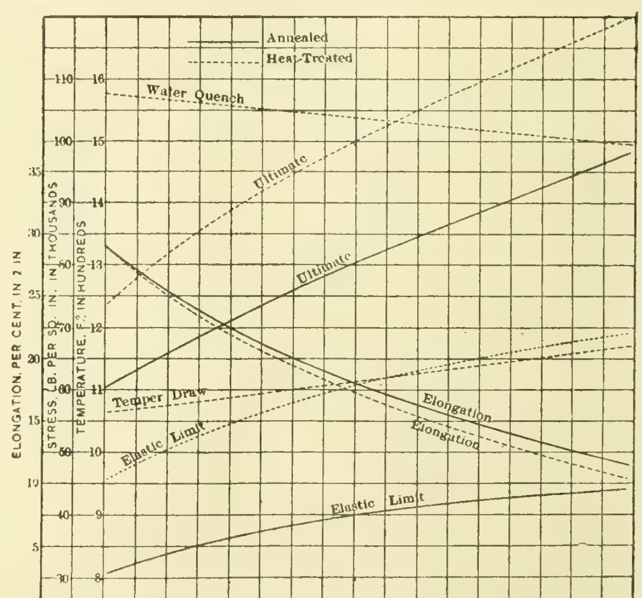


FIG. 1.—CHART SHOWING TESTS OF LARGE CASTINGS.

Heating for Quenching.—Heating for quenching is best conducted slowly, especially in the case of castings of variable thickness. Cracks may occur either in heating or in cooling,

due to different temperatures at different points of the casting. The castings should be thoroughly soaked at the maximum temperature (generally 1,500° to 1,600° Fah.), one hour being sufficient for sections 1ft. in thickness. The minimum temperature which will produce the desired hardening effect will, in all cases, be found to be the most satisfactory, as the grain coarsens when the critical range is exceeded to too great an extent. All temperatures should be governed by a checked pyrometer with the hot junction to the heated object, and with several couples in a large furnace to ensure a uniform temperature.

Quenching. The casting should be transferred as quickly as possible from the furnace to the quenching bath, and in the case of large castings, such as locomotive frames, this is by no means a simple matter. The larger castings are best handled by means of cranes and rollers. The quenching agent employed is generally water or oil, preferably the former, because of its cheapness and drastic cooling effect, more readily breaking up the coarse cast-steel grain. With intricate castings it is generally best to use oil. With water it is possible to have a large tank and a large running stream, serving to maintain a uniform temperature. Castings should never be thrown in to rest on the bottom of the tank, but should be agitated to prevent the formation of a coating of vapour, retarding the quenching effect. It is also best, whenever possible, to quench the thicker portions first.

Drawing.—Whenever possible the drawing should be done in a bath of some kind, such as lead, barium chloride, a barium chloride-salt mixture, or oil. In the case of large castings this is manifestly impossible, and great care should be exercised in obtaining a uniform temperature in the drawing furnace. The use to which the casting is to be put determines the drawing temperature, railroad work, by reason of the shock and vibration of the road, requiring high ductility at the sacrifice of some strength.

The following table shows the heat treatment and the results of tensile and chemical tests:—

	Commercially Annealed.				Heat Treated.			
Bolster No.	B43	B18	B2	B29	B10	B39	B15	BB
E. L., lbs.	30,950	36,700	36,070	41,990	44,663	61,940	61,390	54,930
T. S., lbs.	57,610	78,665	74,020	69,783	80,393	87,890	92,750	84,290
Elon. in 2in., per cent.	14·8	6·0	12·3	5·3	13·2	4·3	11·7	17·3
Red. of area, per cent.	26·8	4·5	16·0	5·9	19·0	7·7	15·4	27·3
C., per cent.	0·31	0·51	0·35	0·49	0·32	0·33	0·33	0·30
M., per cent.	0·82	0·68	0·63	0·70	0·62	0·88	0·76	0·62
Si., per cent.	0·34	0·31	0·36	0·34	0·26	0·41	0·37	0·36
P., per cent.	0·016	0·045	0·036	0·036	0·042	0·014	0·041	0·032
S., per cent.	0·010	0·030	0·016	0·042	0·030	0·025	0·029	0·018
Annealed at, deg. Fah.	1,500	1,550	1,550	1,550	1,580	1,640	1,600	......
Quenched in water at, deg. Fah.	......	......	......	......	1,600	1,600	1,600	1,600
Drawn to, deg. Fah.	......	......	......	......	900	900	900	900

The curves, Fig. 1, show the average results of a considerable number of tensile tests made from large castings. It will be observed that the heat treatment increases the elastic limit about 50 per cent. and the ultimate strength about 25 per cent., without any material change in elongation. The heat treatment to produce these results is also shown. In cases where a fair amount of ductility is required, it is not desirable to have the carbon content above 0·35 per cent. Individual results will vary from 5 to 10 per cent. from the average results.

Nottingham Society of Engineers.—At a meeting of this society, held on Wednesday last, a paper on "The Utilisation of Exhaust Steam, and the Approximate Cost of Producing Electrical Energy therefrom" was read by Mr. W. C. Mountain. He first described the chief types of turbines in use, and afterwards furnished figures showing the amount of steam required by turbines when working on high and low pressure. The amount of exhaust steam available from winding engines and the power to be obtained therefrom was touched on, as well as the units produced by turbines of different capacities under varying load factors, and the approximate cost of producing current with turbines of various sizes under varying load factors. The paper was illustrated by lantern slides of typical colliery installations where exhaust steam is utilised, and of the different types of turbines in use.

MANAGEMENT OF OIL-FUEL PLANTS.

BY R. T. STROHM

THE management of an oil-burning plant differs very considerably from the management of a coal burning plant because of the rapidity with which any alteration in the rate of firing affects the generation of steam. With a coal fire the response to an increased rate of firing is slow, because it is necessary for the fresh fuel to become heated to the temperature of ignition before it can burn and give off heat. In the case of an oil fire, however, the combustion keeps pace with the rate of feeding the oil, so that an increased flow of oil is immediately followed by an increased generation of heat. The fact that an oil-burning plant is so quickly responsive to alterations in the conditions of combustion makes it necessary to observe care in the regulation of the burners and the control of the air supply. It is particularly necessary to guard against the admission of too much air, which will dilute the products of combustion and cause loss of heat. A fireman accustomed to the use of solid fuel may find it difficult to learn to reduce the air supply sufficiently for the economic burning of oil, as oil requires a much smaller excess of air.

The method to be used in starting an oil fire under a boiler will depend on whether the boiler is the only one in the plant or whether there are other boilers already under steam. If steam is not available from some auxiliary source, it is necessary to start an ordinary wood fire and get up steam pressure enough to atomise the oil. If the boiler is one that has been converted from coal burning to oil burning, and the grates are still in place, covered with firebrick, the wood fire is built right on the firebrick layer and is kept going until the steam gauge on the boiler shows a pressure of at least 20lbs., which will be sufficient to atomise the oil for starting the fire. It is not necessary to remove the burner while this fire is under way, but the fire should be kept at a safe distance from the burner.

When the steam pressure reaches 20lbs. the oil pressure pump should be started and the steam valve on the burner should be opened. Steam should be allowed to blow through the burner until the issuing jet appears to be dry. Then the oil valve is opened and oil is allowed to flow into the burner. The spray of oil will be directed into the wood fire on the floor of the furnace and will be ignited, after which the burner will continue its operation in the usual way. The wood fire may be allowed to burn out or it may be raked out after the oil fire has been started.

If there are other boilers in use, so that a supply of steam is at hand, the operation of starting an oil fire under a cold boiler is made much simpler and shorter. The first thing to do is to open the damper to its full extent. The steam and oil stop valves are kept closed, but the needle valve or oil-regulating valve is opened slightly. Now steam is admitted to the burner and is allowed to flow until the pipes and the burner are heated and the issuing current seems to be dry, which indicates that there is no condensation collected in the steam-supply system. Next, a bunch of waste saturated with oil should be lighted and placed inside the furnace, on the firebrick, directly in the path of the steam blast. Then the fire door should be closed quickly and the oil valve should be opened. The oil will flow though the partly opened needle valve or oil-regulating valve and the spray will be ignited by the burning waste. After the fire is thus started, the combustion may be regulated by adjusting the flow of oil and steam and by changing the air supply through manipulation of the ash-pit doors and the damper.

Before starting the fire, it is a wise precaution to blow steam through the oil side of the burner to make sure that the oil passages are clear. This is done by opening the by-pass valve and the steam valve. After the fire is started the intensity of the fire should not be increased too rapidly, as there is danger in forcing the fires under a cold boiler. The condition of the fire is observed through peep holes that are placed in front of the setting or at the sides. When the boiler and its setting have become heated to the usual working temperature the interior of the furnace should appear to be filled with flame, the colour of which should verge on a dazzling white. The flame should be steady and not surging or gusty. An experienced fireman can judge the condition of his fire very accurately by observing the colour of the flame, but it is advantageous if he can also see the top of the chimney.

The combustion of oil is accompanied by a roaring noise, and the nature of this roaring also serves as a guide to the conditions existing in the furnace. It is noticeable that an excessive supply of cold air greatly increases the noise, and that preheating of the air supply renders the combustion much quieter. It is natural to suppose, therefore, that the reduction of roaring in the furnace is accompanied by an increased efficiency of combustion, since it is obtained by cutting down the excess of air and by increasing its temperature. The formation of smoke may be traced to an insufficient supply of air, an over-supply of oil, or too little steam to atomise the oil thoroughly. A burner that has not been properly cleaned and that is clogged or imperfectly adjusted will produce an unsteady flame and may cause smoke. If there are scintillating particles in the flame and they appear to fall to the floor of the furnace, it may be concluded that the atomisation is imperfect. The pressure of the atomising agent should therefore be increased. If there is water in the oil or in the steam, the burner will spit and act erratically. A similar sputtering may be caused by the presence of gases in the oil, due to an excessive heating of the oil on its way to the burner.

In the average small plant using liquid fuel the burners are regulated by hand to accommodate the rate of firing to the demand for steam. This can be done readily because the number of burners to be adjusted is not great ; but in a very large plant this method of control would be irksome particularly if the load were subject to wide and frequent changes. With hand regulation of the separate burners the economy depends on the intelligence of the fireman in judging the conditions of combustion and in the quickness with which he adjusts the burners to changes of load.

Automatic regulation is employed in some of the larger plants. The means by which regulation is effected varies, but the end attained is the same, namely, an increase or decrease in the rate of firing to correspond to an increase or decrease of load. An increased demand for steam is evidenced by a decrease of steam pressure in a boiler. One system of automatic control therefore uses a regulating valve on the oil line to the burners. This valve determines the rate of flow of the oil, and its stem is attached to a spring and to a diaphragm that is acted on by the steam pressure. The pressure of the spring and the steam pressure act to oppose each other, and the tension of the spring can be altered to suit conditions. By setting this spring to the proper tension, any decrease of steam pressure following an increased load on the boiler will allow the spring to open the valve slightly and more oil will be admitted to the burners. In this way the rate of combustion can be made to follow the demand for steam very closely. In this system the pressure of the oil as supplied by the pump remains constant.

In another system of automatic regulation the regulating valve takes the form of a pump governor. When an increase of load comes on, the governor admits more steam to the pump, which increases its speed and gives a higher oil pressure. The oil valves at the burners are left open, and the result of the higher pressure is an increased flow of oil. There is a greater amount of heat thus generated and the steam pressure is quickly brought back to normal by the accelerated evaporation. While the steam pressure is increasing the governor is gradually cutting down the speed of the pump. In this way the steam pressure is kept fairly uniform. Of course, an increased flow of oil demands an increased flow of steam to atomise it properly. In the system of control just described the steam supply is regulated by a valve whose stem is fastened to a diaphragm acted on by the oil pressure. An increased oil pressure immediately causes an increased opening of the steam valve, and thus the correct ratio of steam to oil is maintained.

The draught required for the burning of oil fuel is very small, ranging from about $\frac{1}{8}$in. to $\frac{1}{4}$in. of water. This is much less than is required for the burning of solid fuels and is accounted for by the fact that in an oil-burning boiler the only resistance to be overcome by the draught is that due to the friction of the gases in passing through the furnace, among or through the tubes and along the breeching and the chimney to the outer air. In a coal-burning boiler the draught must not only overcome these resistances but must also cause the air supply to rise through the bed of fuel on the grates. For this reason the chimney of a coal-burning plant will give too strong a draught when the fuel is changed to oil, and to prevent the inrush of too much air the damper must be closed to a greater extent than when solid fuel is used.

The regulation of the air supply to the furnace may be effected either by means of the damper alone or by means of the damper and the ash-pit doors. When the damper alone is used, the ash-pit doors are left wide open and the rate at which air flows into the furnace is controlled by the amount of opening of the damper. The advantage of this system of control is that at all times there is ample opening for the admission of air, and the air enters at a rate sufficient to replace the gases that escape to the chimney. By impeding the escape of hot gases at the damper the hot products of combustion are kept in contact with the boiler surfaces for a longer period and the rate of travel is reduced, thus giving ample time for complete combustion.

It is probable, however, that in the larger number of plants the regulation is accomplished by both the damper and the ash-pit doors. When the load on the boiler decreases the amounts of air and oil are reduced. This results in a corresponding reduction of theweight of gases formed in the furnace, and so the damper should be moved toward its closed position. When the demand for steam increases the opposite adjustment must be made. In any case, the object to be attained is efficient combustion, and this should be done with the least possible amount of air. To judge as to when this point has been reached, the air supply may be cut down until smoke is formed, indicating that there is too little air. Then the supply may be increased gradually until the smoke disappears and only a slight haze is visible at the top of the chimney.

When an oil-burning boiler is to be shut down, the stop valve on the oil line to the burners should be closed first of all, thus cutting off the flow of oil and stopping combustion in the furnace. Next, the steam valve should be closed until only a small jet of steam escapes from the burner. The oil side of the burner should then be blown out, which is done by opening the oil regulating valve on the burner, the by-pass valve, and then the steam valve. This precaution is necessary to prevent clogging of the burner; for if the oil is allowed to remain stagnant in the burner and its connecting pipes, the heat of the setting will carbonise the oil and bake its tarry constituents on the inside of the passages, and there will be trouble and delay when the burner is again put into service. The ash-pit doors and any other openings for the admission of cold air to the furnace should be closed and the damper opened, so that the setting may not cool too rapidly.

As a usual thing, the heat stored in the brick lining of the furnace will re-ignite the oil spray if the flow of oil is interrupted for a few seconds. If the supply of oil is cut off for some time, however, the temperature of the furnace may fall to such a point that the oil cannot be ignited by the heat of the firebrick. In such a case the fireman should shut off all oil and then close the steam valve, putting the burners out of action. Then he should throw a bunch of burning waste into the furnace, close the fire door and restart the burner in the usual way. The inflammable nature of oil fuel renders accidental fires a possibility. Should oil escape from the pipes and become ignited, the flames should be smothered by scattering sand or earth over the surface of the blazing liquid. The air is thus shut off from the oil and combustion dies out because of the lack of oxygen. It is useless to attempt to put out an oil fire by turning water on it, because the only effect of the water will be to spread the oil without extinguishing the flame.—"Electrical World."

ELECTRICAL PYROMETRY.

(*Concluded from page 220*).

"Pyrodur" Indicators.—By virtue of the considerable electromotive force developed by the "Pyrodur" couples, Messrs. Schäffer & Budenberg have been enabled to construct a series of very robust indicating instruments particularly suitable for industrial requirements. For general use a vertical type is made either with flange at back of case (see Fig. 10) for fixing to a wall or switchboard, or with flange in front of case for letting in flush with wall (see Fig. 11), and a portable type (see Fig. 12).

The tubes of "Marquardt Masse," the highest grade of porcelain made by the Imperial German Porcelain Works, at Berlin, withstand a temperature of considerably above 3,000° Fah. and are impervious to gases. They are, however, sensitive to sudden changes of temperature and must not be plunged, when cold, into heat or withdrawn suddenly. They should be inserted slowly or allowed to heat up with the furnace. They must, further, be protected against mechanical injury or exposure to a sharp jet of flame.

A very suitable protection is the new "Silidur" protector introduced by Messrs. Schäffer & Budenberg, Ltd., Manchester. This new kind of protection sheath, which has recently been placed on the market, is chiefly intended as an extra protection to thermo-couples with "Marquardt Masse"

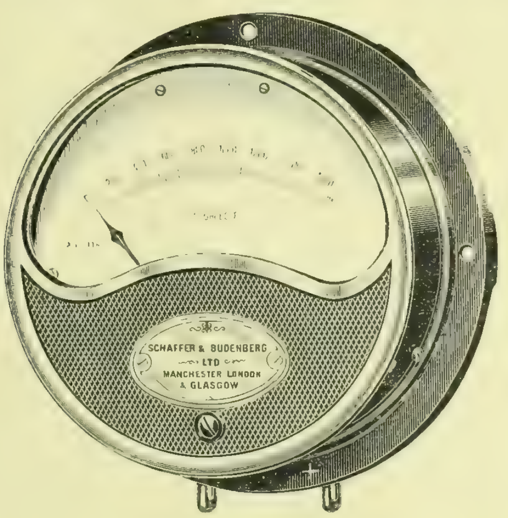


Fig. 10.

tubes, when used under very severe conditions. It is a wonderfully refractory material, which will stand where any other material would be ruined in a very short time.

The "Silidur" sheaths withstand the most abrupt changes of temperature up to 1,500° C. (2,732° Fah.). They protect the Marquardt Masse tubes against cracking, even at most sudden changes of temperature. In comparison with ceramic products, such as porcelain, fireclay, or with quartz, &c., they possess an extraordinarily great mechanical firmness, and in addition resist chemical action well. The only apparent disadvantage of "Silidur" is that it cannot be used alone for a protection fitting, as it is an electrical conductor, and would also affect or destroy the platinum wires, if brought into direct contact with them. This, of course, does not apply if the sheaths, as is recommended, are used as an extra protection over "Marquardt Masse" tubes.

The "Silidur" sheaths should be fixed to the head of the couple by means of a double iron clamp, which is supplied for the purpose, and not to the fragile Marquardt Masse tube. Either of these instruments is made with scale either 1,650° Fah., or 900° C., as shown in Figs. 13 and 14.

For the platinum-platinum-rhodium couples for temperatures up to 1,600° C., or 3,000° Fah., the following indicators are used: (*a*) Precision pyrometer indicator, Fig. 15, horizontal pattern, in metal case, with spirit-level in centre of dial and levelling screws, scale with temperature and millivolts marking and mirror below pointer to avoid errors in reading due to parallax. (*b*) Pyrometer indicator, Fig. 16, wall type, in metal case, with projecting profile scale marked in temperature and millivolts. (*c*) Portable pyrometer indicator, Fig. 17, in walnut case, with temperature and millivolts scale and mirror below pointer to avoid errors due to parallax. Scale, 70° to 3,000° Fah.

Fig. 18 shows the scale of Fig. 15 or 17, Fig. 19 that of Fig. 16 indicator. The scale of the indicators Figs. 15, 16, 17 need not necessarily be extended from 70° to 3,000° Fah. (20° to 1,600° C.), but can be calibrated from 70° to 2,200° Fah. (20° to 1,200° C.) so as to obtain as open a scale as

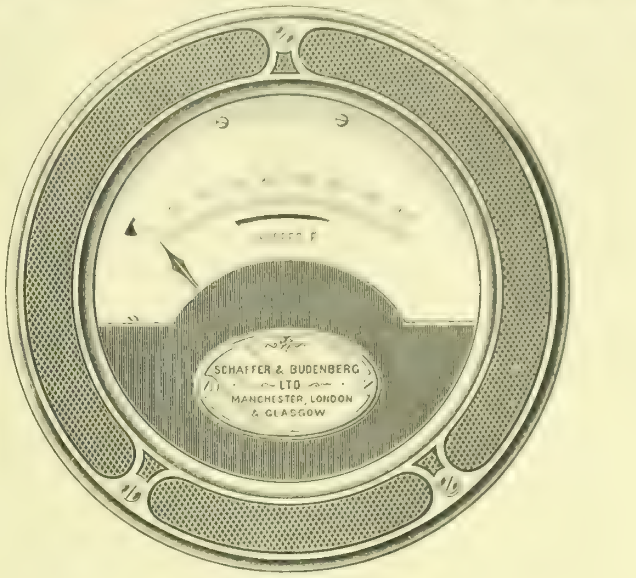


Fig. 11.

possible for lower ranges. The indicators Figs. 15, 16, 17 can also be supplied with two different temperature scales, say, 20° to 1,200° and 70° to 3,000°, or any other convenient range. The second scale takes the place of the usual millivolts scale. The two scales cannot, of course, be used at the same time. Portable double instruments are also made consisting of one pyrometer indicator and one resistance thermo-indicator in one case.

The electrical pyrometers are also made to automatically record the temperature near the source of heat, or at a distant point out of reach of the operator. Messrs. Schäffer and Budenberg make three distinct types of recorder—(*a*) a short period recorder with drum for holding paper; (*b*) a long period type with continuous paper strip; and (*c*) a "multi"

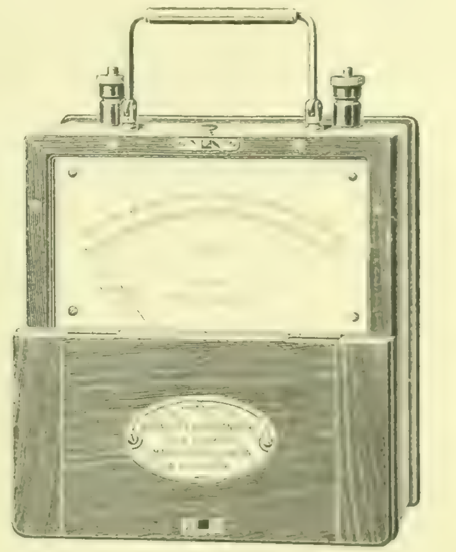


Fig. 12.

continuous recorder to register simultaneously the temperatures of from two to six couples. All these are of the highest perfection of design and workmanship, and the recording system employed is entirely free from pen friction, so that absolutely correct results are ensured.

Any of the thermo-couples described in the foregoing can be connected to two or three indicators, one of which may be fitted near the furnace, in full view of the operator who controls the firing, and one or two at distant offices, or one

indicator may be fixed near the furnace and a recorder in the office. Moreover, a number of stations may be controlled from a switchboard fitted in the office or some central place. One indicator is only required, which is switched in turn to each station.

Fig. 20 shows a simple recorder of the single-drum type. These instruments are supplied in a metal case, and can be



FIG. 13.



FIG. 14.

used on any table which is fairly horizontal. They are normally arranged for a record of 24 hours, but are made for any other period. The drum is revolved by a powerful clock movement, which must be rewound every 24 hours by means of a key. By means of a clock-actuated pressure bar the pointer and writing boom are momentarily depressed once every 30 secs., thus recording, through a copying ribbon, the slightest variations of temperature by a series of connected dots on to the paper fixed on the drum. The momentary temperature is indicated at the same time by the upper

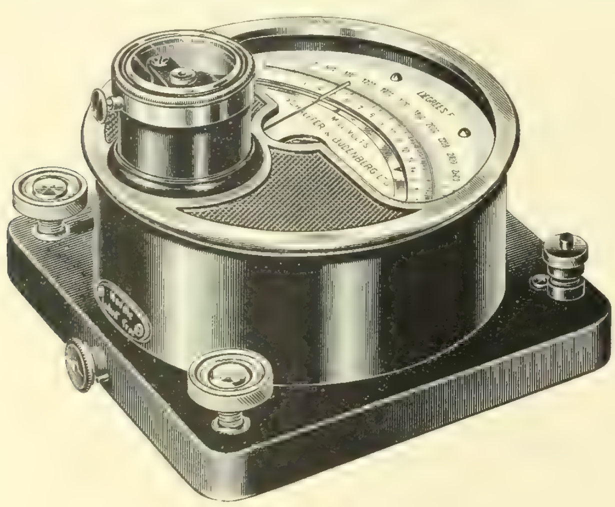


FIG. 15.

extension of the writing boom or pointer on a segment scale visible through the glass in the top of the case.

The width of the paper is $4\frac{5}{8}$in. and the length $13\frac{3}{4}$in. The paper is divided by vertical hour lines and horizontal temperature lines. The papers are normally divided as follows:—

From 30 — 1,650° Fah.	(or 20 — 900° Cent.)	}	for Pyrodur couples.
,, 30 — 1,100° ,,	(or 20 - 600° ,,		
,, 70 — 3,000° ,,	(or 20 - 1,600° ,,	}	for Platinum-Platinum-Rhodium couples.
,, 70 — 2,200° ,,	(or 20 — 1,200° ,,		

The papers are, however, supplied with any lower range according to requirements, so as to give as clear a record as possible for the working range.

Figs. 21 and 22 show fragment scales of the recorder Fig. 20—1,600° Fah. as obtained with pyrodur couple and 3,000° Fah. as obtained with platinum-platinum-rhodium couples. During the transit the writing boom is arrested by a flat spring at the left or zero end of the scale. To start the recorder this spring is depressed and the writing boom gently pushed to the right. The clock is then started by a lever on the right-hand side of the case.

Each time after re-winding the clock movement, the winding key must be withdrawn and the dust cap over the keyhole closed. If no graphic record is required, the instrument can still be used as indicator of the momentary temperatures, by leaving the writing boom unlocked whilst stopping the clock movement. The pressure bar which depresses the writing boom is arrested automatically by the opening of the outer case, so that therefore the registration can only take place when the case is closed.

Fig. 23 shows a recorder of the continuous paper type. These instruments are supplied in metal case, and can be used on any table or bracket which is fairly horizontal. The diagram paper is 50 yards long, and runs out through a slot in the front of the case at either of the following rates: (*a*) Rate of paper feed $1\frac{3}{16}$in. (30 mm.) per hour, registration taking place every 60 secs. The paper lasts 60 days, whilst the clock movement must be re-wound every seven days. (*b*) Rate of paper feed $2\frac{3}{8}$in. (60 mm.) per hour, registration

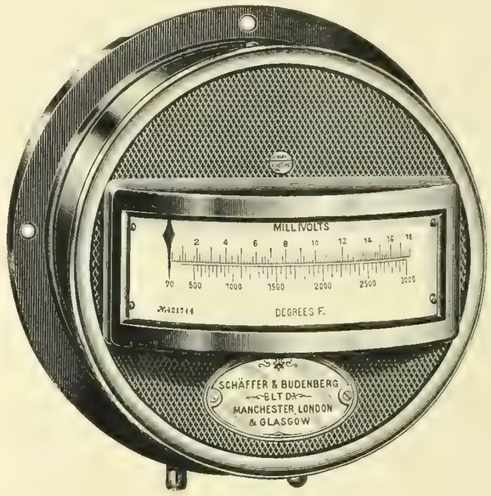


FIG. 16.

taking place every 30 secs. The paper lasts 30 days, whilst the clock movement must be re-wound every three days.

The tip of the pointer or writing boom is momentarily depressed every 30 secs. or 60 secs. against the paper band as it passes over an ink-pad, by means of a clock-actuated pressure bar, thus recording every minute variation of the temperature by a series of closely-spaced dots. The paper being transparent, the dots are visible on both sides. An ingenious but simple recording mechanism ensures a system

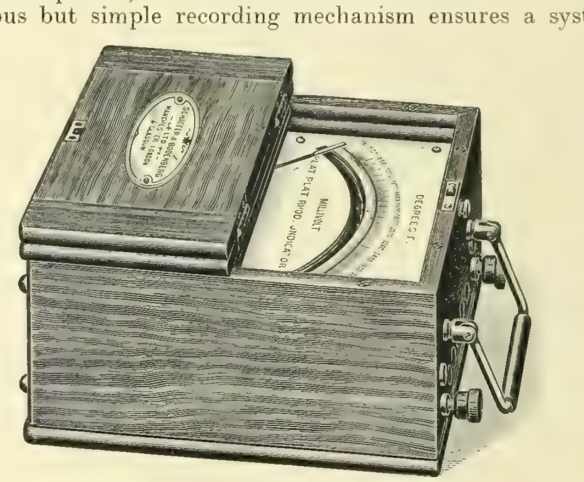


FIG. 17.

of straight ordinates. The papers are normally divided as follows:—

From 30 — 1,650° Fah.	(or 20 — 900° Cent.)	}	for Pyrodur couples.
,, 30 — 1,100° ,,	(or 20 600° ,,		
,, 70 — 3,000° ,,	(or 20 — 1,600° ,,	}	for Platinum-Platinum-Rhodium couples.
,, 70 — 2,200° ,,	(or 20 — 1,200° ,,		

Figs. 24 and 25 shows fragments of the records of Fig. 23—1,600° Fah. as used with the pyrodur couples and 3,000° Fah. as used with platinum-platinum-rhodium couples. The adjustment of the pointer to the temperature prevalent near

the head or "cold junction" of the thermo-couple is effected by means of a screw on the top of the case marked Index Correction. The electric recording system is arrested by throwing the lever A on right side of base over to "Locked." The paper is changed or adjusted after sliding the glass door in front to the left (which can only be done after the lever A

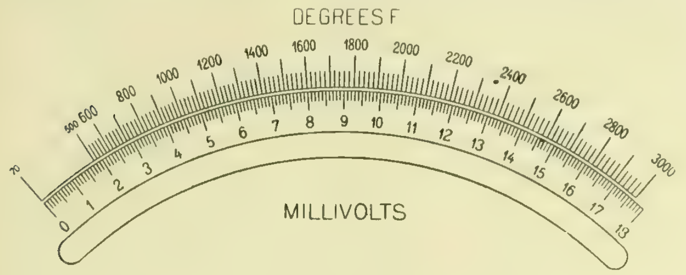


FIG. 18.

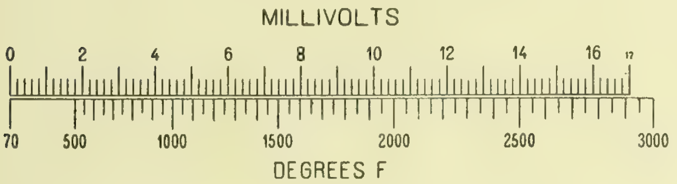


FIG. 19.

is thrown over to "Locked"). The clock movement is re-wound by a key. To start the movement the milled knob on top of case is turned to "Free."

In Fig. 26 we have a continuous recorder to register simultaneously the temperature of from two to six stations. We recently had the pleasure to inspect one of these instruments installed at Messrs. Schäffer & Budenberg's premises to record room and outdoor temperatures, and we must candidly admit that it is as interesting a piece of mechanism

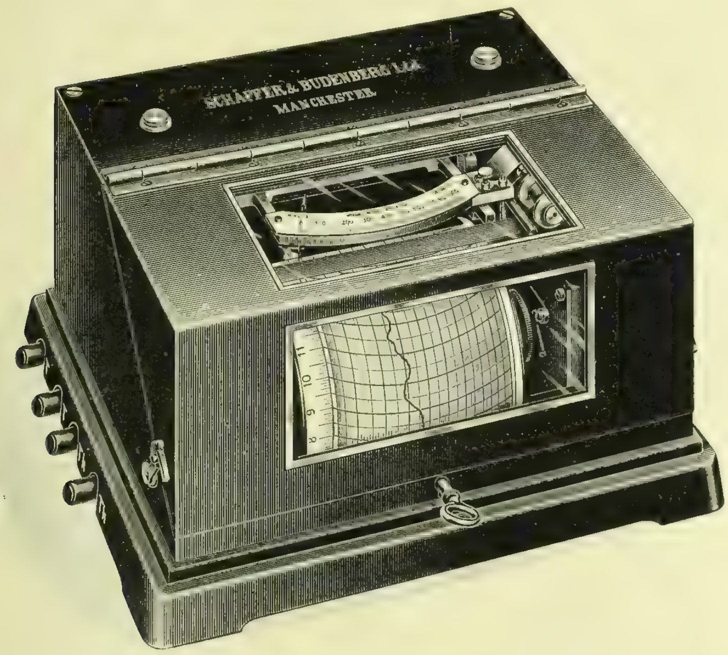


FIG. 20.

as we have seen for many a day. One scarcely knows what to admire most, the ingenious design or the exquisite finish of every detail or the marvellous, almost uncanny, precision with which the instrument works. It is quite fascinating to watch the writing boom or needle taking its position within a fraction of a degree for each of the six stations successively. In the instrument which we saw, and which, we learn, Messrs. Schäffer & Budenberg will be glad to show to any of our readers, the slightest variation of temperature caused by opening a door or a window, or by lighting, regulating, or extinguishing the gas fire in a calorifier in one of the rooms, is instantly recorded, as also the differences in the case of outdoor temperatures caused by the effect of wind or direct sunlight.

The makers claim the following advantages for these instruments, viz.: Records from two to six thermo-couples on one chart; each record in a different colour and quite distinct; highest precision of workmanship; works quite automatically; requires little attention; paper easily changed; no inking of pens, &c.; momentary temperatures indicated on large open scale. And, as far as we can judge, these are fully borne out in practice.

The instruments are arranged to hang on a wall and record simultaneously on a chart, 50 yards long, the temperatures at from two to six different places. The various temperature curves are produced in different colours and can be recognised very distinctly, even if they cross each other at acute angles. The multi-colour effect is produced by the employment of a hexagonal roller with six pads, each charged

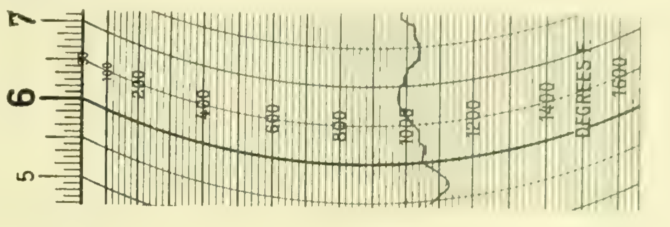


FIG. 21.

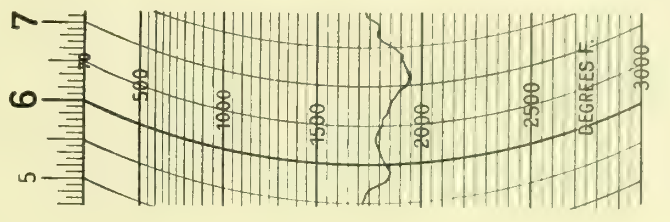


FIG. 22.

with ink of different colour. This roller is revolved automatically, so that the corresponding colour is turned up as each element is connected in its turn to the recording system. Thus the temperatures of the various stations are recorded each in its own different colour. The temperature, which is recorded momentarily, is indicated by a pointer on a scale at the top of the instrument. A figure wheel on the right indicates the number of the thermometer which is in circuit.

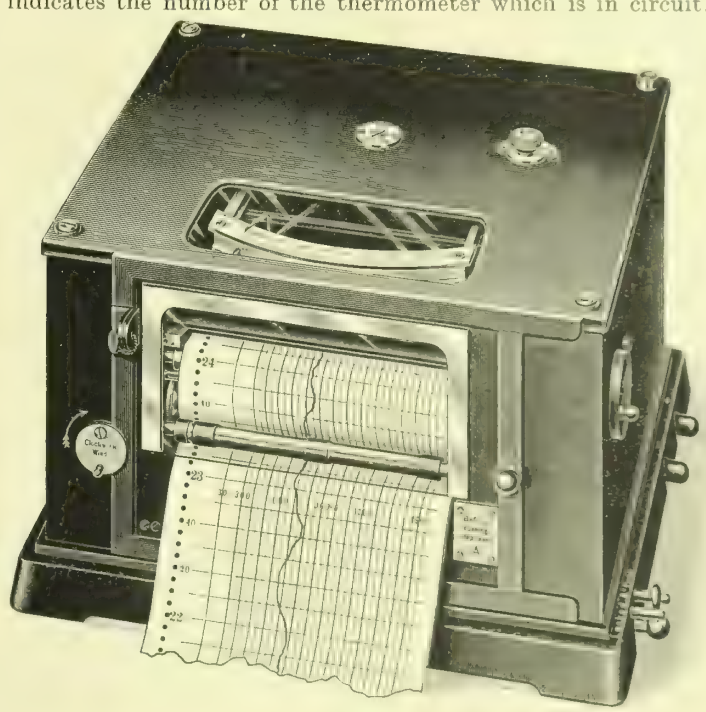


FIG. 23.

The figures on this wheel are in different coloured enamels corresponding to the colours of the respective record curves.

The instruments are supplied with either of the following paper speeds and recording periods, &c.: (a) Paper speed $1\frac{3}{16}$ in. (30 mm.) per hour. The registration takes place every 30 secs., each of the six thermometers being put into the circuit every 3 mins. The paper lasts 60 days. The clock

goes 14 days. (*b*) Paper speed 2⅜in. (60 mm.) per hour. The registration takes place every 15 secs., each of the six thermometers being put into the circuit every 1½ mins. The paper lasts 30 days. The clock goes seven days.

In each case the record curves consist of series of closely-

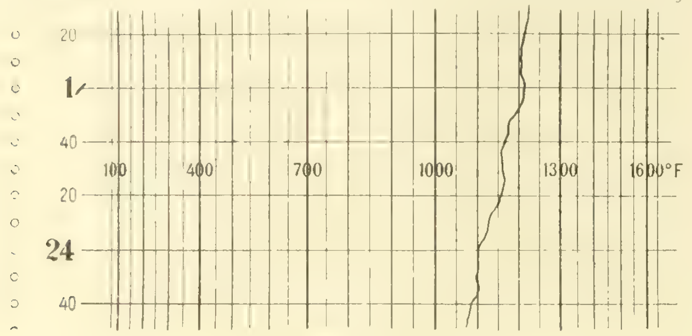


Fig. 24.

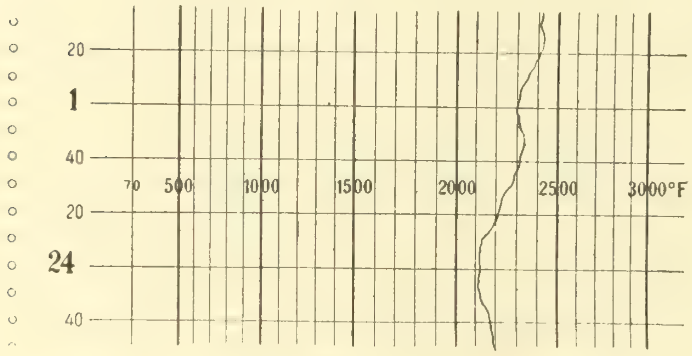


Fig. 25.

spaced dots forming practically complete lines. The instrument is arranged in a case with lock-up glass-fronted cover. When once fixed and connected it requires no attention beyond occasional winding of the clock and changing of the

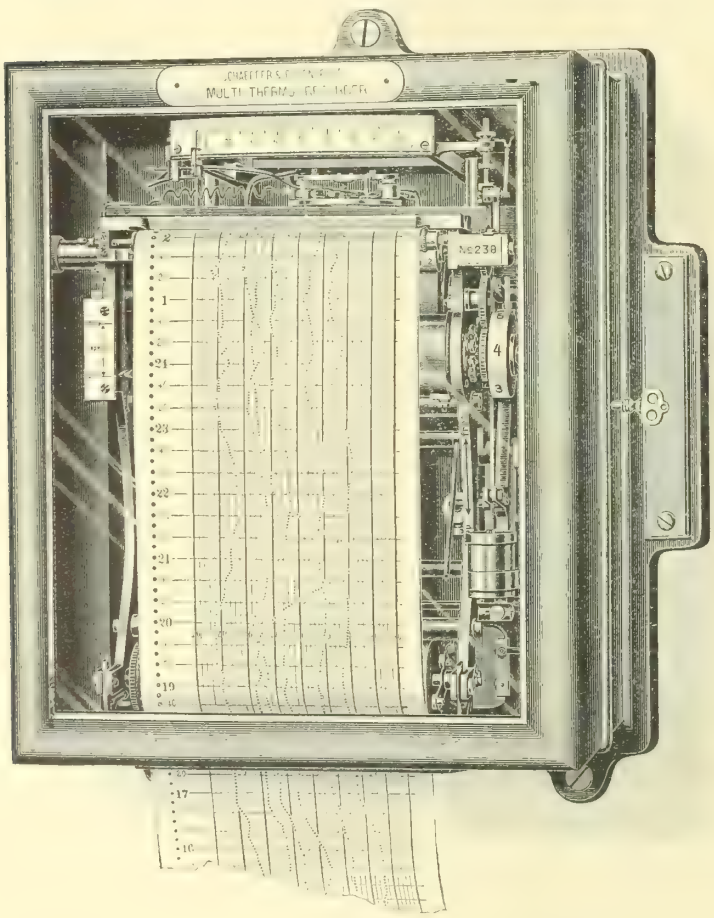


Fig. 26.

paper. The ink-pads in the recording roller last for a considerable time, but can be re-charged, when necessary, at a small cost. The power required to work the electromagnetic switch for putting the different thermo-couples intermittently into circuit is usually supplied by a small three-cell accumulator or battery, or, if preferred, a resistance can be supplied, so that any existing electric light or power can be used. The papers (in rolls of 50 yards each) are normally divided as follows:—

From 30 — 1,650° Fah. (or 20 — 900° Cent.)		for Pyrodur couples
,, 30 — 1,100° ,, (or 20 — 600° ,,)		
,, 70 — 3,000° ,, (or 20 — 1,600° ,,)		for Platinum-Platinum Rhodium couples.
,, 70 — 2,200° ,, (or 20 — 1,200° ,,)		

BREAKDOWN OF A D.C. MOTOR ARMATURE.*

BY F. CHURCH.

THE armature belonged to a totally-enclosed 40 h.p. four-pole machine, having a multiple-circuit winding. The diameter of the armature was 15in. The commutator lugs were 2·75in. long, the commutator diameter 8in., and the overall diameter of the lugs 13·5in. The copper and carbon dust produced by the friction between the brushes and the commutator was carried by the ventilating current of air through the open spaces between the commutator lugs and into the interior of the armature. This action was continuous while the machine was running, and in course of time the rear of the commutator segments, mica, and commutator sleeve became covered with particles of copper and carbon. The insulating

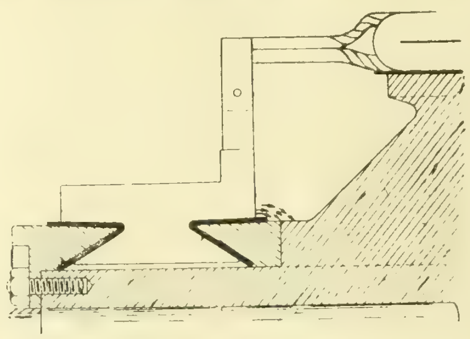


Fig. 1.

lacquer, when warm, retained the dust, thus forming a path between the live commutator segments and the armature core. As the dust accumulated the insulation resistance gradually decreased, but this was carefully watched and the armature eventually removed.

A further test revealed the position of the fault, which extended from the segments across the mica, as shown in Fig. 1. During this test small arcs could be seen on the film of copper dust, passing from the commutator to the metal sleeve. Before a remedy could be applied it was necessary to remove all the copper and carbon dust behind the commutator. The question was how to get at it so as to enable a good repair to be made in quick time. The following method was adopted: Sufficient conductors were unsweated at the three parts, A, B, and C (Fig. 2), so as to enable small steel scrapers to be used over the whole surface covered with the copper dust. The scrapers were made in different shapes, so that all crevices, &c., could be thoroughly cleared of copper dust and old lacquer. The back of the commutator segments was thoroughly cleaned, and also the exposed mica between and underneath them. Insulation tests were made during the process, and the improved results obtained amply repaid the trouble. The last test gave a value of 5 megohms. The armature was then baked to a temperature of 100° Fah., and when tested later, at intervals of 24 hours, the following results were obtained: (1) 7·5 megs.; (2) 20 megs.; (3) 50 megs.

The writer conceived the idea of removing the moisture from the armature by means of resistance wire wound circumferentially round the armature, strips of wood being placed lengthways along the core to keep the resistance wire from touching the armature. After the wire had been wound on the armature, a sheet of asbestos was placed so as to completely enclose it, and thus prevent loss of heat. The

* Paper read at the Midland branch of the Association of Mining Electrical Engineers, and reproduced from "The Iron and Coal Trades Review."

wire used was 160 yards of No. 22 manganin, asbestos covered. Resistance per yard = 0·976. The pressure used was 250 volts, and the current passing through the wire was 1·6 ampere.

Whilst the armature was hot the exposed portion of the commutator sleeve was well coated with "Voltalac," which is an air-drying lacquer. Afterwards a single layer of cotton tape was wound round the sleeve. The lacquer was applied to the back of the commutator segments in a thin layer and allowed to dry. When thoroughly dry, the whole of the interior was given a second coating of "Voltalac." When

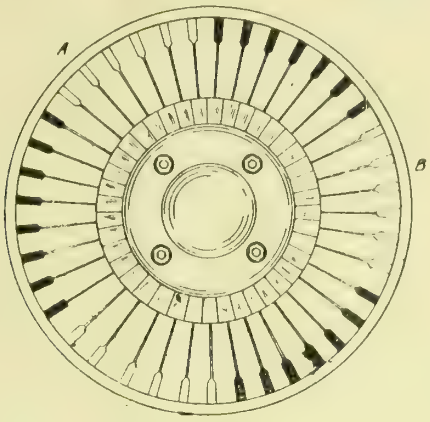


Fig. 2.

this was dry a layer of brown paper was laid over the lacquered parts, and then the conductors were re-sweated into their respective lugs, care being taken to have the conductors and lug to be sweated in such a position that the solder ran away from, and not into, the interior of the armature. The cord binder was then placed in position and the temperature of the armature raised to 100° Fah. At this temperature a final coat of lacquer was given to all connections, &c., which had been disturbed. The armature was subjected to the above temperature for three days, and

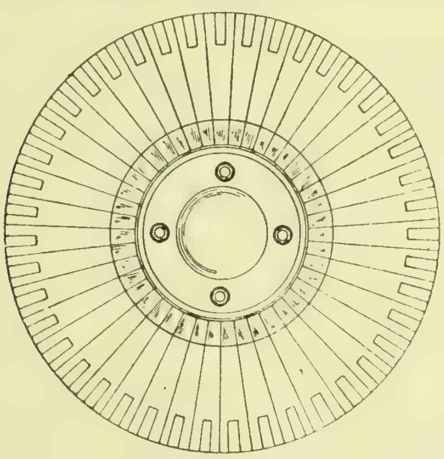


Fig. 3.

the final test gave 70 megs. When the armature was cold the insulation was at 20 megs.

To prevent this kind of failure the space between the commutator lugs must be filled in so as to make it impossible for the copper and carbon dust to pass through. The commutator segment and lug should be made in one piece, and the mica extended to the top as shown in Fig. 3. With armatures up to 20 h.p., the lugs can be made short and the ends of the conductors laid obliquely from the lugs to the slots. Impregnated tape should be laid beneath the conductors to prevent any dust passing between them to the back of the commutator.

The above remarks apply chiefly to the semi and totally-enclosed motors. The open type of machine is not so liable to fail from the above cause.

North-east Coast Institution of Engineers and Shipbuilders.—At the general meeting of the Graduate Section, to be held in the Institution, on Saturday, March 14th, at 7-15 p.m., a paper on "Screw Propellers," by Mr. P. Y. Brimblecombe, B.Sc., will be read and discussed.

MOTOR AND CONTROL EQUIPMENTS FOR ELECTRIC LOCOMOTIVES.*

By F. Lydall.

Motors.

Dealing first with motors for locomotives, it will be convenient to divide them into two classes, viz., geared and gearless motors. The suitability of one class in preference to the other in any particular case has already been discussed at some length in a previous paper.† The conclusions arrived at are that the sphere of utility of the geared motor is practically confined to locomotives of moderate speed, as, for instance, locomotives whose maximum speed never exceeds 60 to 65 miles per hour; whereas for express passenger locomotives, with which speeds up to 80 or 85 miles per hour may be reached, the gearless motor practically holds the field. It is proposed only to draw attention to questions of motor capacity in relation to (*a*) gauge, (*b*) electrical system, (*c*) voltage, (*d*) diameter of driving wheel, (*e*) method of transmission, and (*f*) forced ventilation.

(*a*) *Gauge.*—It will be readily understood that a narrow gauge hampers the designer very seriously. If it is intended to adopt the ordinary form of transmission, viz., by single reduction gearing with the "wheelbarrow" type of suspension, the space available for the motor and the gearing is equal in one direction to the distance between the wheel tyres, less the necessary clearance. If with the normal-sized driving wheel the space available is insufficient to accommodate a motor of the required capacity, the only alternatives are to increase the wheel diameter or to adopt some other form of transmission. The latter of these two alternatives leads to a more expensive construction, but nevertheless it may be unavoidable.

The point is well illustrated by two locomotives both equipped by Messrs. Siemens Schuckert, one for a colliery in the North of England, the other for the metre-gauge railway line belonging to the Rombacher Hütte in Alsace. In the latter the motors are suspended on the bogies in the ordinary way, and the only departure from the usual arrangement is in respect of the wheel diameter which is greater than customary for motors of 160 h.p. capacity. This instance is of particular interest owing to the fact that each motor is designed for a voltage of 1,000, and is insulated sufficiently to withstand a pressure of 2,000 volts to earth, the supply being at 2,000 volts continuous current. In the former locomotive, which was designed for a gauge of 26in., the problem was to provide an equipment with a total capacity of about 175 h.p. For this purpose an 88 h.p. motor was mounted on each of the two bogies in such a position that it was not restricted in an axial direction by the wheel tyres. A jack shaft was also provided geared to the motor and coupled to the driving axles by side coupling rods. In this way a motor which with the ordinary suspension could not be got into any gauge less than one metre was fitted on to a truck built for 26in. The two constructions are shown to the same scale in Fig. 1. The restrictions of gauge are of less importance in a locomotive in which gearless motors are used mounted in the body of the locomotive and driving by connecting rods and jack shafts. With this construction the motor can be made as large in diameter as desired consistent with the limits of armature peripheral velocity, but in an axial direction it is limited by the distance between the centres of the crank pins at the two ends of the jack shaft. With outside bearings, however, the cranks being on extensions of the journals, this is not a severe restriction.

(*b*) *and* (*c*) *Electrical System and Voltage.*—Four alternative systems may be mentioned: Continuous current low-tension, continuous current high-tension, three-phase alternating current, single-phase alternating current. For continuous current, low tension may be regarded as any voltage up to 750 or 800, high tension 1,000 volts upwards, there being no cases that the author is aware of in which the voltage is between 800 and 1,000. It will be obvious that for the same capacity a high-tension motor will be larger and heavier

* Abstract of paper read before the Institution of Electrical Engineers.
† F. Lydall. "Electric Locomotives." Journal I.E.E., Vol. LI., p. 790, 1913.

than a low-tension motor. There is less space for armature conductors, and therefore the armature must be bigger for the same volume of copper. The commutator may be shorter if the motor is designed for a high terminal voltage, and not merely insulated for connection in series with another low-voltage motor on a high-tension supply; but this advantage is counter-balanced by the longer creeping surfaces required and the greater clearances between live parts and the frame. Space in an axial direction being in general restricted, the tendency will naturally be towards an increase in the diameter, corresponding to an increase in the working voltage, as has already been noticed in the case of the Rombacher Hütte locomotive mentioned above.

question of frequency is important. For three-phase locomotive motors, especially those operating in cascade, a low frequency is desirable. In the new locomotives for the Norfolk and Western Railway 25-frequency motors are to be used, but this is probably on account of the general tendency in the United States to adopt this frequency as the lowest standard for railway work in order to utilise the supply for other purposes at the same time. So far as capacity in relation to weight and bulk is concerned, polyphase induction motors make a very good showing. It must be remembered, however, in comparing induction motors with motors having series characteristics, whether continuous-current or single-phase alternating-current, that the induction motor is rated

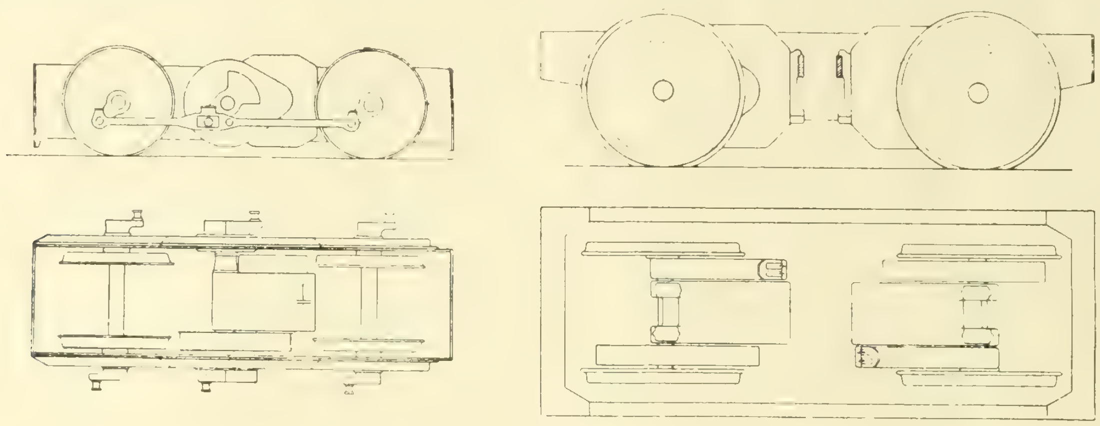


FIG. 1.

For motors of moderate capacity, there seems no difficulty in raising the supply voltage to 2,400, as in the case of the locomotives for the Butte and Anaconda Railroad, each of which is equipped with four 300 h.p. single-reduction twin-gear forced-draught motors suspended in the ordinary way with 48in. driving wheels. A step in advance of this is being tested on the Lancashire and Yorkshire Railway, where motor-coach equipments are being supplied by Messrs. Dick, Kerr, & Co., each consisting of four 250 h.p. 1,650 volt single-reduction single-geared motors with driving wheels of 44in. diam., the supply voltage being 3,300. These equipments are said to work perfectly satisfactorily, but it is self-evident that

at its maximum speed, that is, at a speed which may correspond to the maximum permissible peripheral velocity of the rotor, whereas the series motor is rated on the basis of a speed which may be, and often is, not more than half the maximum. If series motors were especially designed to give their output on the one-hour rating at their maximum speeds, they would compare very favourably with induction motors; at least the continuous-current series motor would give astonishing figures for weight per horse-power. In practice, the single-phase motor, even at the low frequency adopted as the standard on the Continent ($16\frac{2}{3}$ or 15) is undoubtedly more bulky than the continuous-current motor. As an illustration of this,

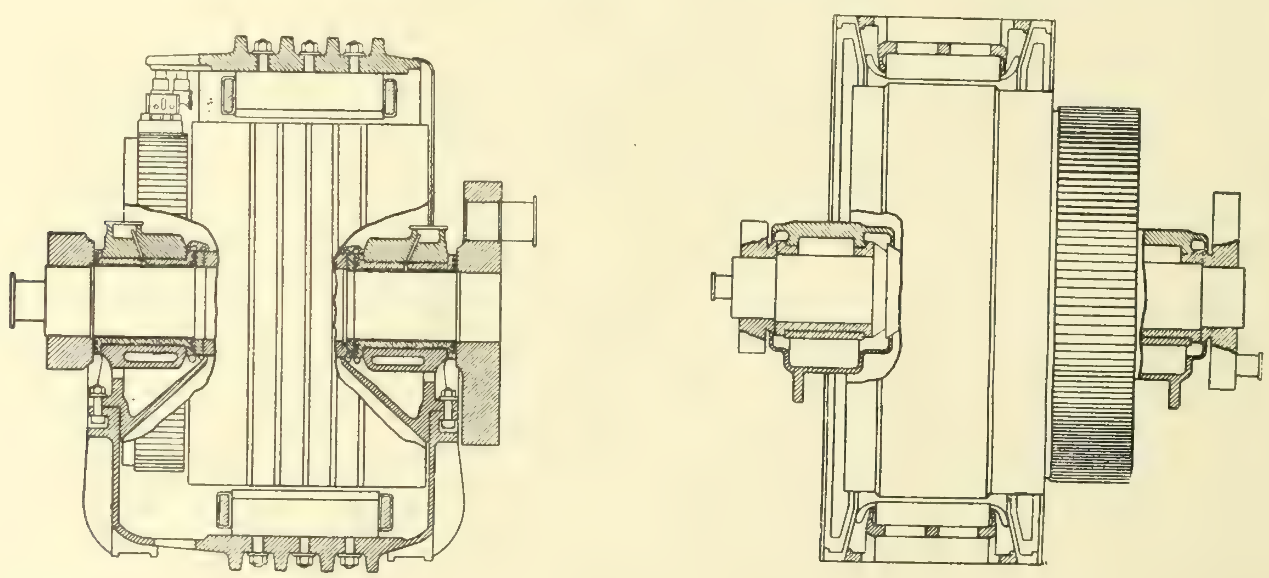


FIG. 2.

2,000 H.P. 600-volt Motor, for Pennsylvania Locomotives.

800 H.P. Single-phase Motor, I — B + B — I, Locomotive for Lötschberg Railway.

in some places inside the motor the clearances between live parts and the frame must be comparatively small. But whatever the results of this experiment may be, it is certain that in the case of a locomotive where there is no objection to the motors projecting above the floor level, the electrical designer would feel happier in making the motor with ample internal clearances, and this could only be done by freeing the motor, by one or other of the various methods available, from the restrictions of the gauge and the wheel diameter.

In considering the two alternating-current systems, the the 2,000 h.p. 600 volt motor of the Pennsylvania Railroad locomotives may be compared with the 800 h.p. single-phase motor of the Lötschberg locomotive equipped by the Allgemeine Elektricitäts Gesellschaft. The comparison is shown in Fig. 2, the two motors being drawn to the same scale. The influence of the two factors (*d*) and (*e*) on motor capacity has already been touched upon above.

(*f*) *Forced Ventilation.*—The advantage of forced ventilation in increasing the continuous capacity is so great that it is becoming general to introduce it in locomotives of all

classes except small industrial locomotives. The complication of apparatus involved in the provision of the blowers is not great, and no trouble in regard to maintenance need be anticipated, as the blowers and their motors can be fixed in the interior of the locomotive, where they can be inspected at any time.

CONTROL EQUIPMENTS.

The problems inherent in the design of a control system suitable for an electric locomotive are bound to depend upon the purpose which the locomotive is intended to serve. It may be said at once that apart from special cases an electric locomotive differs essentially from a motor coach both as to its function and as to its constitution. A motor coach, as generally understood, is a passenger vehicle with an electrical equipment. This equipment is usually designed to enable the train to be started with a high acceleration, so high in

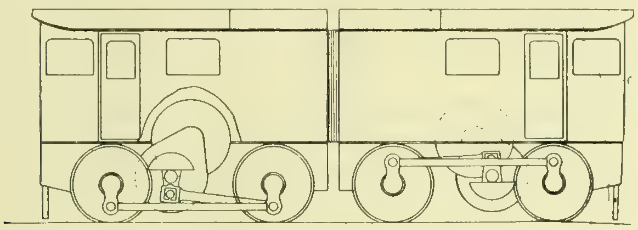


FIG. 3.

fact that it does not depend to any great extent on the gradients such as are ordinarily met with on English railways. The weight of the motor coach is determined principally by structural considerations with regard to the passenger accommodation, and partly by the weight of the electrical equipment itself, and is kept down to the lowest limit consistent with strength and the requisite capacity.

The design of an electric locomotive, on the other hand, depends on quite different considerations. In the first place, the weight is arbitrarily chosen independently of the structural strength and to a certain extent of the capacity of the equipment; on the contrary, the principal deciding factors are the adhesion necessary to enable the required tractive effort to be exerted, and the speed of travel. The first of these factors determines the weight carried by the driving wheels; the second the number and arrangement of non-driving wheels. In many cases locomotives are ballasted in order to bring up the total weight to the required value. In the second place, electric locomotives are not usually intended for service in which high acceleration is required. Rapid starting is not a matter of great impcrtance for freight trains or for long-distance passenger trains. In consequence the proportion of the weight on the driving wheels to the total weight of the train is usually much lower in the case of trains hauled by electric locomotives than in the case of multiple-unit motor and trailer-coach trains. For example, for freight trains the ratio might perhaps be as low as 1 to 20; whereas for multiple-unit trains it would seldom be less than 1 to $2\frac{1}{2}$, or 1 to 3. This difference in the ratio of adhesion weight to total weight has a marked influence on the control system, as will be seen the moment the question of starting on gradients is considered.

The following general statements with regard to heavy traction by steam or by electric locomotives will be admitted by railway engineers: (*a*) The weight on a pair of driving wheels is generally not far from the maximum permissible weight as determined by the strength of the track, bridges, &c. (*b*) A locomotive is utilised to the greatest advantage when it is coupled to the heaviest train with which it is able to deal; that is, haul at the regulation speed on the line selected, start on the steepest rising gradient, and stop on the maximum falling gradient.

It will perhaps be best to explain the influence of these points on the control system by considering a simple example. Let it be assumed that the maximum weight per axle of the locomotive is 16 tons; and take the case of an articulated four-axle 64-ton locomotive, each half of which is equipped with one continuous-current motor, driving through single-reduction gearing and coupling rods. Suppose also that the steepest gradient on the line is 1 in 90. Fig. 3 shows the outline of the locomotive, and Fig. 4 gives the performance curves of each motor. In order to study the capabilities of the locomotive it is necessary to make some reasonable assumption as to the maximum value of the coefficient of adhesion. Let it be assumed that this value is 1 to 4, in other words that the greatest tractive effort than can be exerted by the motors without causing the wheels to slip is 64/4 tons (=16 tons) measured at the tread of the driving wheels (not at the draw-bar).

Now the variations of the tractive effort exerted by the motors during the progress of the controller obviously depend on the number of steps in which the controlling resistances are switched out with motors in series and in parallel. Whatever the variation may be, the current on each position of the controller must be allowed to fall so far that when the next step of resistance is switched out the current does not increase beyond the value corresponding to the maximum permissible tractive effort. If the load behind the locomotive when travelling up the specified gradient is too great, the current will never fall sufficiently to permit the controller to progress without causing the wheels to slip. It is, of course, well known that when the wheels slip the tractive effort is much less than while the wheels adhere to the rails. If, therefore, the load is excessive, the locomotive will be unable to start the train and gather speed on the gradient, although it may be perfectly capable of maintaining full speed up the gradient if the train has already been started on the level or on an easier gradient. Thus suppose the locomotive mentioned above is coupled to a train weighing W tons, and assume that the tractive resistance of the whole train during the start is 7lbs. per ton, then the tractive effort required to maintain speed on the gradient of 1 in 90 without acceleration will be—

$$(W+64)\left[\frac{2240}{90}+7\right]$$
$$=(W+64)\ 32\text{lbs.}$$
$$=\frac{W}{70}+0{\cdot}915\text{ ton.}$$

This then will be the theoretical lower limit of the variation of tractive effort during the start. For example, supposing the number of steps in the control system is such that with

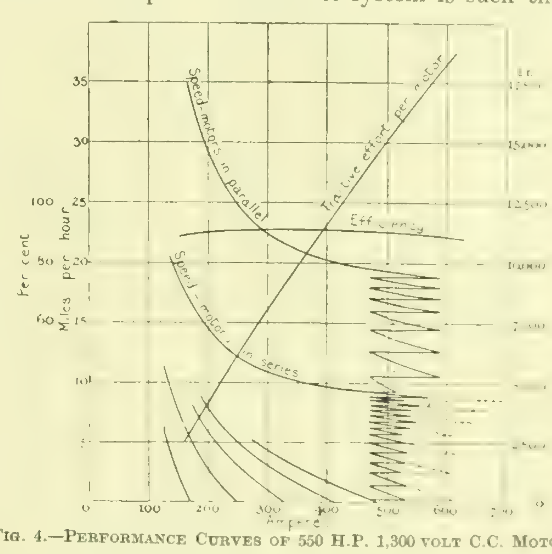


FIG. 4.—PERFORMANCE CURVES OF 550 H.P. 1,300 VOLT C.C. MOTOR.

an upper limit of 16 tons the lower limit is 12·5 tons, then the maximum train weight permissible will be given by the equation

$$\frac{W}{70}+0{\cdot}915=12{\cdot}5,$$

from which W=810 tons. It is hardly practicable, however, on the assumptions made above, to work with a trailing load as high as this. If this load were coupled to the engine and an attempt were made to start up on the specified gradient, each step of the control would occupy an inordinate time before the motor current fell far enough to permit the controller to advance to the next step. This is fairly obvious from the speed time curve in Fig. 5, which shows how the acceleration varies from a fairly high value down to almost

zero on each position of the controller. If then the maximum theoretical load is attached to the locomotive, the acceleration must actually reach zero on each position of the controller, which is, of course, impracticable. In practice, therefore, the load must be limited to something less than the theoretical maximum value. For the following reason the reduction will depend on the gradient. If the tractive resistance is small compared with the force of gravity on the gradient, the pull required to maintain speed on the gradient can be calculated with fair accuracy. If not, the calculation will depend to a large extent on a correct forecast of the tractive resistance. Even a correct forecast, however, is not sufficient, since the tractive resistance differs between wide limits under varying conditions. For example, suppose the gradient in question is 1 in 50, and the estimated tractive resistance is 7lbs. per ton. Then the pull corresponding to steady speed will be—

$$\frac{2240}{50} + 7\text{lbs. per ton} = 51{\cdot}8\text{lbs. per ton.}$$

An error of 10 per cent. in the tractive resistance will only involve an error of 1·25 per cent. in the total. If, however, the gradient were 1 in 200, an error of 10 per cent. in the tractive resistance would lead to an error in the total of 3·8 per cent. The only safe way then is to estimate the tractive resistance on the high side and allow a margin beyond the calculated value to ensure that the starting period is not unduly prolonged. For example, in the case illustrated in Fig. 5, the theoretical maximum value is 810 tons, and the actual value on the basis of which the curves have been drawn is only 740 tons. The number of steps in the controller or control system will depend on the characteristics of the motor in question. If the magnetic circuit of the motor is not highly saturated on that part of its range which is used during starting, and if the resistance of the motor is relatively high, the number of steps necessary to keep the torque variation within moderate limits is not likely to be excessive. The greater the saturation and the lower the internal resistance, the greater will be the number of steps.

These two factors can be combined in one, viz., the slope of the speed curve at the working range. The greater the slope, the smaller the number of steps. This slope being the resultant of the two factors will vary with different motors. In a general way one may say that the bigger the motors, the lower will be the internal resistance, and therefore the less the slope and the greater the number of steps. This is illustrated by the comparison in Figs. 4 and 6, the former of

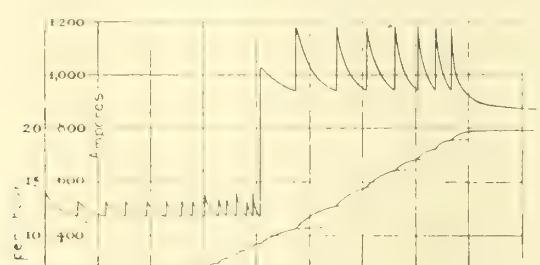


Fig. 4.—Acceleration Curve of 810-ton Train 1 in 100.

which shows the starting curves for a 550 h.p. motor and the latter those for a 100 h.p. motor, the same percentage variation of torque being permitted in both cases.

This comparison is perhaps worth consideration when determining the most favourable motor equipment for a given locomotive. If a single large motor be chosen instead of, say, four small motors of the same aggregate capacity, in order to arrive at the same value of the maximum permissible load a more elaborate control system must be installed. This is, however, comparatively a small point.

It is also worth remarking that the question of self-induction in the motor windings does not enter into the consideration of the problem. In the case of a tramcar starting on the level, under ordinary circumstances the entire starting period may not last more than six seconds, and therefore the time spent on each notch of the controller is so short that the variations of the motor current may be considerably influenced by self-induction. In the case of a locomotive starting with its maximum load on a steep gradient, the accelerating period may last from five to ten minutes, so that the influence of self-induction may be ignored. It is, therefore, necessary to consider the matter carefully, as no help can be expected from this source.

On the other hand there are two factors which make for some uncertainty as to the precise fluctuations of the torque

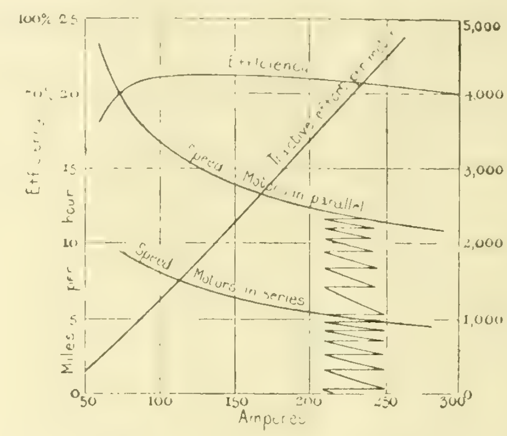


Fig. 6.—Performance Curves of 100 H.P. 500 volt C.C. Motor

during the accelerating period, viz., the variation of the supply voltage on the overhead line, or on the third rail as the case may be, and the variations in the resistance values of the controlling resistances due to the rise in temperature. The first of these tends to reduce the fluctuations, as the supply of voltage will generally fall slightly as more current flows through the motors. The second is very uncertain, the temperature of the resistances depending on the working conditions, &c.

(To be continued.)

LATHE FOR CRANK PINS.

The accompanying illustrations show a design of self-contained lathe for turning the pins of crank shafts and other similar pieces, the invention of Mr. G. A. Ryder, Turner Bridge Ironworks, Tonge, Bolton. Fig. 1 is a front elevation of the lathe, and Fig. 2 is a part sectional plan of the same with the loose headstock removed. Figs. 3 and 4 are end elevations taken respectively from opposite ends of the barrel, Figs. 1 and 2.

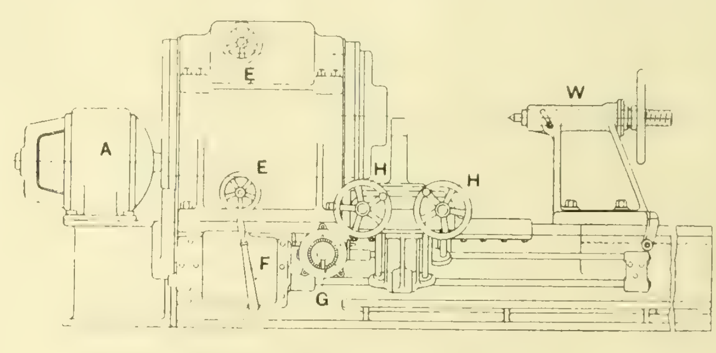


Fig. 1.
Lathe for Crank Pins.

Figs. 5, 6, and 7 are detail views, on a larger scale, of a suitable arrangement of gearing for adjusting the position of the outer sliding carriage in the rotating barrel.

Referring to the illustrations, A designates an electric or other suitable motor; B a gear box containing the variable gearing for rotating the barrel at the required speeds; C the main pinion gearing into external teeth on the rotating barrel D; E two hand wheels for controlling the gears in the gear box B and effecting the necessary changes to alter the speed of the barrel D as required; F the usual change-feed motion lever; G a speed controller for automatically controlling the motor A and thereby maintaining the cutting speed at one constant rate; H two hand wheel controls for the

usual cutting tools; and W the customary loose tailstock. In the rotating barrel D is mounted a longitudinally sliding carriage J on keyways K, and in this carriage is mounted in guides an inner carriage M arranged to receive the end of the crank shaft in one or other of two bearings X. The carriage M is adjusted to the desired degree of eccentricity to suit the throw of the crank shaft by means of a hand wheel N, a pair of bevel wheels O, and a screw P in engagement with a lug Q

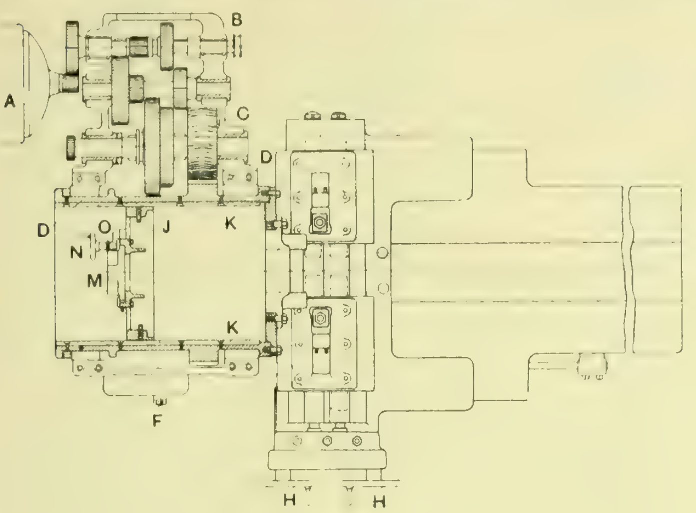
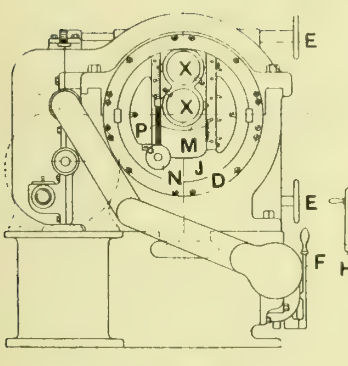


FIG. 2.



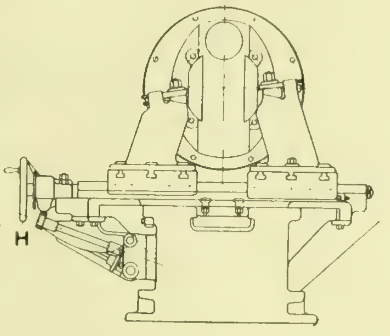


FIG. 3. FIG. 4.

LATHE FOR CRANK PINS.

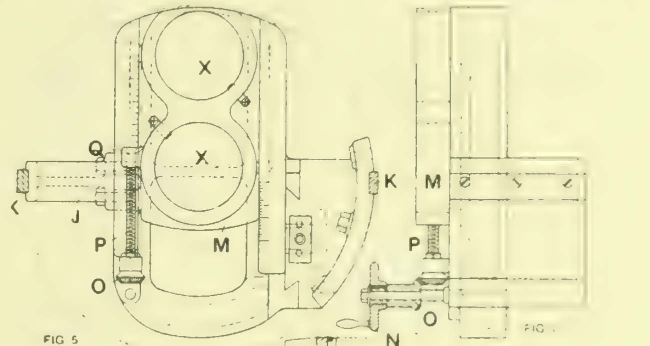
on the inner carriage M. On the guides of the carriage M are provided suitable graduations, and indicating fingers (Fig. 3) to facilitate setting the carriage M.

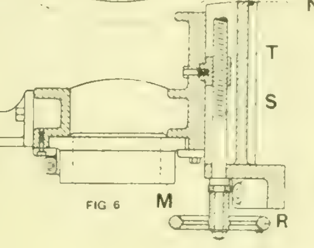
As first one crank pin and then another is turned the carriage J has to be made to slide in the barrel D on the keyways K, the motion being either applied direct by hand or by mechanism such as that shown in Figs. 5, 6, and 7. This mechanism comprises a hand wheel R and screw S, the latter engaging a nut T on the carriage J. It will therefore be seen that as the hand wheel R is turned the carriage J is caused to slide along the barrel D and is locked and held stationary until the hand wheel R is again turned. In operation the motor A drives through the gears in the gear box B, the main pinion C, which through the teeth drives the barrel D and the carriages J and M with the crank shaft are caused to rotate whilst a crank pin is being turned. When one crank pin has been finished it becomes necessary to feed the carriage J further into the barrel D, and this operation can be effected in either manner described.

PNEUMATIC TOOLS.*

BY H. I. BRACKENBURY.

ALTHOUGH chipping and riveting hammers have been known and used for many years in shipyards, their use in English yards is still very limited, and this remark applies more especially to the riveting hammer. With a few exceptions our shipyards make less use of these tools than might have been expected from the examples set by other countries and the known excellency of the work produced by pneumatic riveting hammers. During the last year there has been an exceptional demand for hands for shipbuilding, and there was difficulty in finding a sufficient number of riveting squads. The result was that the entire output of the shipping trade, on which depends the bulk of our English trade, was limited by the number of rivets which could be closed each day. There are few, if any, rivets in a ship which cannot be closed with a pneumatic hammer, and a very conservative estimate of the rate of riveting with a pneumatic hammer would be as two to one driven by the hand hammer. A rough estimate of the rivets driven in ships in the British Islands for the year 1913 was 280,000,000. This figure gives some idea of the effect on production which would be made by a full use of pneumatic tools. The question may well be asked why the shipbuilders have not used to the full the advantages offered them. The answer is, the difficulty of overcoming natural opposition to the introduction of labour-saving tools. But in the meantime are we not perhaps starving the goose that lays the golden eggs, and may we not wake from this boom of trade to find the continental shipyards in a position to enter into very serious competition with us in the trade that means so much to our country? Japan is using the tools extensively, and it is to be feared that a





LATHE FOR CRANK PINS.

Japanese riveter, armed with a pneumatic hammer, may be more than a match for our English riveter when using a hand riveting hammer. The days when physical strength was everything have passed, both for war and trade, and one may look with serious concern to the future of our country unless full use is made of modern inventions to increase our powers of production.

The pneumatic hammer, reduced to its lowest terms, is a combination of a cylinder, reciprocating piston, a valve controlling the flow of motive fluid to and from the cylinder, and a throttle valve in the supply pipe. Considered in this light, credit must be given to James Watt, Savary, and others, as the original inventors. All the earlier engines were designed to produce rotary motion or to work pumps, with or without crank and flywheel. The idea of using a free piston was first suggested as a good means of rock drilling. Amongst the earliest inventors in this field was George Low, an Englishman, who in 1865 patented a rock drill having a hammering piston. He states in the specification that his device can be used for riveting, &c., but it was in no sense of the word a hand tool. Low is perhaps chiefly interesting as being the first to show a grasping handle with manually-operated throttle valve within the control of the operator's fingers.

Low was followed two years later by Doering, another Englishman, with a rock drill which shows originality of design. He was the first to patent a pressure-operated valve for this class of machine, in which the piston and valve are mutually interdependent for their respective motions, that is, the valve controls the motion of the piston, and the piston performs the double function of striking the blow and acting as a valve to control the motion of the valve itself, a principle

* Abstract of paper read before the Coventry Engineering Society, Coventry, January 23rd, 1914.

which, in many forms and modifications, is used on all modern pneumatic hammers. The first to patent a hand pneumatic hammer was Dr. S. W. Dennis, a San Francisco dentist, who was granted a patent in 1877 for a pneumatic dental mallet (United States Patent No. 195,102). This tool had a valve which controlled the admission and exhaust of the compressed air to and from one end of the cylinder only. The piston in moving outward to strike its blow compressed a spring which, after exhaust took place, reset the piston for the next working stroke. The compressed air was supplied by a small foot power compressor. This device did not come into general use.

The first serious attempt to produce a practical metal-working pneumatic hammer seems to have been made by Boyer, of St. Louis, who, in 1883, patented a "chipping machine" provided with a grasping handle and a throttle valve controlled by hand. In principle Boyer appears to have followed somewhat the lines of Dr. Dennis. Instead of using a spring for resetting the piston, Boyer used a piston of two diameters, and, under the shoulder so provided, used constant air pressure on a small area for this purpose. The piston, in its working stroke, therefore operated against this constant pressure, tending to hold it in its rearward position. The valve in Boyer's first device was thrown backward and forward by means of a stud projecting laterally from the piston engaging a slotted extension of the valve stem. The valve was placed in a chamber close alongside the cylinder and parallel to it. Nothing came of this device, and Boyer seems to have done nothing further in this field for about 12 years or more.

Now we come to the invention of Benjamin Brazelle, of St. Louis, who in the early 'eighties obtained a patent in the United States of America for a steam pump, disclosing a differential-area piston attached to a pump plunger, together with a differential-area valve, each of which served to control the operation of the other. Brazelle's device is not very different from Doering's, but he used a differential-area piston in connection with a differential-area valve, and the construction is in consequence simpler than that of Doering. Brazelle states in his specification that his machine may be used not only for pumping, but for "working hammers or stamps, rock drilling, and the like." Boyer seems to have drawn inspiration from Brazelle's invention, for in 1896 he brought out a metal-working pneumatic hammer involving Brazelle's design, but modified to suit the conditions of chipping, caulking, and riveting. About this time other inventors had placed on the market pneumatic hammers of the valveless type which were used for stone cutting, and in a small way for caulking ship and tank plates. These hammers were necessarily of very short stroke, and depended for their effect upon extremely rapid blows, some of them making from 3,000 to 5,000 strokes a minute. Some of the earliest ones were used in Cramp's shipyard in 1894. These tools were not provided with handles, and they were not only cumbersome, but the vibration was so bad that the workmen objected to using them. Hammers of this type, of small size, are still used largely for stone carving, and are considered the best for the purpose, not only in principle, but on account of low cost. Boyer was followed by Keller, Kimman, Richards, Meissner, and other American inventors, and the pneumatic hammer industry quickly became an important one throughout the world. It was soon found that there was a large field for pneumatic hammers for closing rivets, and that the Boyer and other types of hammers, based more or less on the principle of Doering and Brazelle, and which involved the use of a piston greater in length than the length of its stroke, could not be made sufficiently powerful to do heavy riveting without making them of such dimensions that they would be too heavy to be used by one man.

This demand for pneumatic riveters led to the invention of the "long-stroke" hammer, *i.e.*, one in which a comparatively short piston was made to travel a distance much in excess of its own length. This was the first instance in the pneumatic hammer art which called for original invention. Previously nearly all the so-called inventions had been largely adaptations of inventions in other fields to this particular purpose. Boyer was probably the first to make a long-stroke hammer, and he acomplished it about 1899, by employing a valve at each end of the cylinder, connected together by two rods of small diameter placed in longitudinal passages drilled in the walls of the cylinder. The valves worked simultaneously by means of air pressure created through "cushioning" of the piston as it neared the end of its stroke. The whole was much too intricate and delicate to stand hard service, however, and was soon abandoned.

Meissner, of St. Louis, at about the same time, brought out a long-stroke hammer with one valve only. This valve was so arranged as to be moved in one direction by live air pressure admitted to the smaller of its two differential areas, and in the other direction by pressure created by the "cushioning" of the piston on its return stroke. The design involved "throwing" the piston rearward by air pressure exerted on it through about a third of its stroke, the balance of the stroke being accomplished by its own momentum. A full stroke was assured, however, because the valve, being moved rearwardly by compression of air caused by the piston, would not shift until the full rearward stroke of the latter was accomplished. The Meissner invention assured the success of the "long-stroke" hammer, and the main principle of his invention, which he seems to have failed to protect as broadly as he might have done, has been adopted with modifications by all the makers of pneumatic tools throughout the world.

(*To be continued.*)

INDUSTRIAL AND TRADE NOTES.

Automatic Signalling on the Midland Railway.—The trial Railophone plant laid down by the Midland Railway Company on their main line near Derby has been tested in the presence of some of the directors of the company, and the initial tests are said to have proved very satisfactory. With the railophone the driver is warned by means of an audible signal of the approach to a distant signal, and if the warning is ignored the brakes are automatically applied.

Tyne Tube Railway Bill.—The North and South Shields Railway Bill should have come before the Examiner of Standing Order Proofs, at the House of Commons, on the 4th inst., but there was no appearance on behalf of the promoters, and the Bill is, therefore, dead. The object of the Bill was to authorise the incorporation of a company with a capital of £200,000 and borrowing powers of £65,000 for the making of a new railway a little over three-quarters of a mile long, connecting the boroughs of Tynemouth and South Shields, and passing beneath the Tyne by means of a tunnel.

Electrification of Swedish Railways.—The Swedish railway authorities have prepared a scheme for the extension and improvement of the State railways during the next ten years. The scheme will involve a capital expenditure of over £16,000,000. Of this amount it is proposed to employ £2,640,000 for the electrification of the most important sections of the main lines. It is also proposed to complete the electrification of the Kiiruna Railway—the section between Kiiruna and the port of Luleaa on the Bay of Bothnia. The other section to the Norwegian frontier is already being electrified. The former will involve an expenditure of nearly £420,000.

German-built Locomotives for South African Railways.—The Union of Africa Railways Department has, we learn, recently awarded the contract for ten powerful locomotives to Messrs. J. A. Maffei, of Munich. These engines will not be of German design, but will approximate very closely to locomotives built and building for the South Africa railways at Glasgow, Leeds, Newton-le-Willows, Darlington, and other locomotive building shops in this country. They are to be constructed according to designs prepared by the chief mechanical engineer of the South Africa railways. The question of early delivery was the determining factor in this order being placed outside Great Britain, as was the case in the placing with a Berlin engineering firm of an order for ten main line express passenger locomotives for the South-Eastern and Chatham Railway Company, announced last month.

Freezing Method of Shaft Sinking.—The freezing at the new Harworth Colliery will consist of putting down bore holes in a circle around the site of the proposed shaft, and by means of a freezing mixture, a solid circular wall, eleven feet in thickness, will be formed, and this will be impervious to water. Around each shaft will be described a circle, 90ft. diam., and within the circumference of the circle will be laid a little endless railway line, upon which four drilling machines will be placed, all drilling simultaneously, and each moving on from point to point, until the complete circle of holes has been bored. The boring will be done by rapid rotary machines. The system has been found successful in the Westphalian coal fields, where there has been as much as 400 yards of water-bearing strata to cope with, whereas at Harworth there is only 120 yards to deal with. The contract for the sinking has been let to a German firm at Essen, and operations will be begun as soon as the necessary equipment has arrived.

The Industrial Uses of Coal Gas.—Mr. H. M. Thornton, vice chairman and managing director of the Richmond Gas Stove and Meter Company, Ltd., London, in a recent lecture on this subject, said the continued increase in the consumption of gas for industrial work by the well known progressive manufacturers in this and other countries, showed clearly that it was regarded as being either more economical than other fuels for heating purposes, or that the work was accomplished better and more quickly. As a matter of fact, it was because gas was found to be both more economical and more satisfactory in its results than other fuels, that its use was becoming increasingly popular. The day was coming, and not far distant, when the gas industry would more and more avail itself of the storage and distribution of coke oven gas. When that became an accomplished fact in this country, as it had already become in Rhenish-Westphalia on a large scale, then gas, popular as it was for industrial work, would be used for the very largest furnaces which at present were fired with hard fuel.

Scarcity of Pig Iron in Russia.—According to the Board of Trade Journal, the Board of Trade are now in receipt, through the Foreign Office, of information to the effect that the Bill embodying the recommendations of the Conference appointed to consider the question of the scarcity of pig iron in Russia, proposes to empower the Council of Ministers to authorise, on separate application in each case, the importation from abroad, until December 31st, 1915, at reduced rates of Customs duty, of pig iron for the needs of the metallurgical industry up to a maximum quantity of 15,000,000 poods. The Bill further authorises government departments and the private railways "to avail them selves of the services of foreign industry at reduced rates of Customs duty." It is stated that the Ministry of Commerce propose to limit the application of the import facilities to castings, forgings, and furnace mouldings, girders and sleepers, rails of all kinds, assorted and shaped iron and steel of all kinds, iron and steel wire of all kinds, sheet and universal iron and steel, and railway rims and axles.

Rescue Work in Mines.—In the printed Parliamentary papers, Mr. McKenna replies to two questions respecting the new Home Office regulation in regard to rescue apparatus in mines. He says: "The reference on the mine owners' objection to the regulation proposed by the Home Office has been partly heard, but, in the course of the proceedings, an arrangement was come to which, if generally accepted, will render the further hearing unnecessary. Under this arrangement the owners agree that self-contained apparatus shall be provided, and the rescue brigades trained in its use, and an alternative system for the establishment of rescue brigades will be admitted by which, in place of local brigades at the collieries, as at present required, permanent brigades will be maintained at the central stations, and one or more men, according to the size of the colliery, will be trained at each mine to act with the central brigade when summoned to the mine. This system has the important advantage of securing brigades more highly trained and efficient than a local brigade, with only occasional practices, can be, and, as the central station must be within ten miles of the mines which it serves and in telephonic communication with them, and must also be provided with a motor-car in constant readiness for transporting the brigades, the central brigades will be able to reach the mine almost as quickly as the local brigade. It will be necessary to propose fresh rules to carry out the arrangement, and this will be done immediately."

British Engine, Boiler, and Electrical Insurance Company, Ltd.—At the annual meeting of the above company, held in Manchester on Tuesday, March 10th, the chairman (Mr. Longridge) in moving the adoption of the report and balance-sheet, remarked that as regards premium income there had been a satisfactory increase in each separate department of their business, but there had also been an increase in claims. In calculating the loss ratio for their class of business, the cost of inspection must be added to actual disbursements for claims, and the figures showed that the insurance of electrical plant was more costly than even the insurance of engines, which again was very much more costly than insurance of boilers. The maintenance of an efficient staff for the work of inspection was of course an expensive matter, but any reduction under this head would inevitably result in an increase of claims, and that inspection was appreciated as a preventive measure was shown by the very satisfactory way in which firms continued to renew their policies even though for a sequence of years there had been no claims to be paid on them. The great increase in the volume of work had necessitated removal to new and more commodious premises at the corner of Fennel Street and Long Millgate, which it was hoped would be occupied within the next six months. It was agreed to pay a dividend of 5s. and bonus of 3s. per share, which, after transferring £10,000 to reserves, would leave £2,818 to be carried forward to next account. Sir George Hayter Chubb and Mr. Norman Fletcher were re-elected as directors, and Messrs. P. & J. Kevan were reappointed as auditors.

Swan, Hunter, & Wigham Richardson, Ltd.—At the annual meeting of this firm, held a few days ago, Dr. G. B. Hunter in moving the adoption of the report said They had launched 21 ships during the year, which corresponded with 18 ships and three floating docks launched in 1912. The tonnage of those vessels was 107,606 as compared with 126,152 in 1912. The indicated horse-power of the ships launched was 109,130, which was an indication of the class of vessel built, and compared favourably with the output of any other shipbuilding firm in the world. Last year's output, reduced as it was, was still large enough to confer upon them what was called the blue riband, which they had held for three years in succession. If they added Messrs. Barclay Curle's output—45,000 tons—their total would have been very much greater. He could not help saying that some classes of their employés had worked very badly. They had not worked on an average more than 37 hours per week. Referring to the question of the developing of the Diesel oil engine, particularly in connection with their Neptune works, he said that these works had had considerable success with these oil engines, and though the demand for this type of engine had lulled for the moment, mainly because of the increased cost of oil, and partly because of the want of success of some of the earlier engines, still he felt that demand would be renewed, and they were in the happy position of being able to meet it when it took place. Both Messrs. Swan, Hunter, and Wigham Richardson, and Messrs. Barclay, Curle, & Co. had taken a leading part in the development of this class of engine, and the new works in Glasgow in which they were interested were specially laid out for building oil engines of large capacity such as would doubtless be required for war vessels.

New Developments in Shipbuilding.—Mr. Fred. J. Stephen, chairman of the Technical Committee of the British Corporation for the Registry of Shipping, in submitting his report at the annual meeting, said each year resembled its predecessor in presenting a constantly increasing volume of work and a variety of technical points, including some entirely new propositions in connection with shipbuilding or marine engineering. The past year had been no exception to the rule. Several vessels had been in service, which carried bulk oil in cylindrical tanks stowed vertically or horizontally in the hold, and there were under construction many vessels which contained a development of the idea in the form of cylindrical tanks of the largest possible diameter built into the ship. This avoided altogether the costly and troublesome systems of stiffening which were necessary to flat-sided tanks. The tendency to specialise was illustrated by three vessels which were built and building for Messrs. Lang & Fulton, Greenock, and were intended for the carriage of steel. Those vessels had each one long hold and one long hatchway, and were so constructed that the girder work which provided the necessary transverse strength and stiffness in way of the long hatchway also formed a cargo space in the middle of the ship, which, by restricting the width over which the cargo could be stowed, raised the height of the cargo and the position of the centre of gravity, thus making the vessel much more comfortable at sea than was possible with the ordinary disposition of heavy cargo. The Technical Committee had had the rules under revision, but had found no reason to depart from their main features. A distinct advance, however, had been made in the regulation for the attachment of the frames to the tank sides, a matter to which the committee had always attached great importance. A rule had also been introduced in which the stiffening of shaft tunnels was based on a more accurate approximation to the water pressures to which they might be subjected in case of accident than that obtained under the somewhat crude methods which had been ordinary registry practice for so many years. The sub-committee on internal-combustion engines continued to give consideration to the provisional construction rules which had been issued by the society with the object of making them as nearly as possible a satisfactory embodiment of present experience. They hoped soon to bring their labours to a conclusion.

The Motor Tank Ship "Sebastian."—The new oil tank steamer "Sebastian," built by the Caledon Shipbuilding Company at Dundee and engined by the Aktiebolaget Diesels-Motorer of Stockholm, recently sailed from London on her maiden voyage. The vessel is fitted with two main Diesel engines having six cylinders of 16in. diam. and 22½in. stroke, and each developing 800 h.p. at 165 revs. per minute., on a fuel consumption of 7½ tons of oil a day. They are of the two-stroke cycle open type. Owing to the use of cylinder ports the only valves in the cylinder crown are the injector and relief valves. The overhead camshaft drives only the fuel valves and the fuel pumps. Fresh water is employed for cooling the pistons, and is itself cooled by the incoming sea-water destined for the cooling of the cylinder jackets and exhaust main. The cooling pumps are driven by the main engines. An emergency air compressor is worked by a Diesel engine, but all the remaining auxiliaries are steam driven.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1912.

Hydraulic transmission gear for power driven vehicles. Lentz. 15781.
Centrifugal pumps, turbines, and condensers. Rees. 26188.
Manufacture of steel. Rombacher Hüttenwerke & Bronn. 29051.

1913.

Variable speed friction gearing. Welford & Welford. 113.
Workmen's time recorders. Gledhill. 914.
Apparatus for utilising exhaust steam. Wadagaki. 957.
Internal combustion engines. Lindsay & Oliver. 1107.
Superheating systems for water tube boilers. Vulcan Werke Hamburg und Stettin Akt.-Ges. 3681.
Universal and ball joints for machinery. Nicholson. 3922.
Fuel injection apparatus for internal combustion engines. Nayler, Nayler, & Nayler. 4049.
Rotary under reaming bits for boring wells. Redfern. 4165.
Variable speed gears. Stanier & Hill. 4449.
Speed control apparatus for mechanically propelled vehicles. Grafton. 4458.
Evaporation of liquid and apparatus therefor. Soc. d'Exploitation de Procedes Evaporatoires Systeme Prache & Bouillon. 4515.
Carburetters of the internal combustion engine type. Gower. 4599.
Water heaters. Julienne & Chambers. 4785.
Hydraulic transmission. Constantinescu. 5152.
Internal combustion percussive machine. Scott. 5146.
Packing rings for pistons. Gaskell. 5547.
Internal combustion engines. Peytoureau et Cie. 5716.
Starting of internal combustion engines. Tate. 5818.
Chain coal cutting machines. Sutcliffe. 6624.
Plant for recovery of zinc from zinc ores. Roitzheim. 6771.
Firing furnaces with pulverised fuel. Brunner. 7267.
Process of dressing ores by means of gas. Takeda. 7272.
Signal systems for railways. Marks. 7585.
Tachometers. Hoeft. 8593.
Apparatus for the introduction of water or other liquids into the cylinders of internal combustion engines. Jackson. 8714.
Pipe joints. Picken. 9231.
Internal combustion motors. Medinger. 10668.
Steam turbine installations. Yarrow. 10998.
Heating of combustion air. Gabriel. 11645.
Internal combustion engines. Roots. 12171.
Cooling and scavenging cylinders of internal combustion engines. Collins, Kerr, & Russell. 12316.
Safety valves. Ross and R. L. Ross & Co. 12605.
Fuel spraying devices for the carburetters of internal combustion engines. McMahon. 12729.
Two speed toothed gear driving mechanism. Goode. 12747.
Liquid fuel spraying devices. Hamill. 12765.
Fuel-injecting devices for oil engines. Gardner & Gardner. 12881.
Two cycle gas engines. Daniel. 13457.
Lifting jacks. Aron & Aron. 13815.
Generation of combustion products under pressure. Dresser. 16846.
Sparking plugs. Marks. 17514.
Making or refining steel. Humbert. 18116.
Liquid fuel burners. Smith. 18571.
Devices for atomising liquid fuel. Hofmann. 18610.
Hydraulic motors. Miyares. 19187.
Internal combustion turbine engines. Engles & Like. 19769.
Power cylinders for internal-combustion engines. Hiehle. 21531.
Apparatus for charging coke ovens. Puschmann. 22763.
Mechanism for the linear transmission of power. W. Butcher and Sons, Ltd. and Butcher. 23172.
Indicating the level of lubricating oil in engine crank cases. Buck. 24287.
Clutches. Harpers, Ltd., and Mowat. 24725.
Cutting tools for use in lathes. Gardner. 25382.
Ore roasting furnaces. Bracq. 26736.
Train stopping devices. Hudson. 27179.
Air pressure brakes. Geb. Korting Akt. Ges. 28666.

1914.

Cutting discs for metal cutting machines. Mars Werke Akt. Ges. 674.

ELECTRICAL, 1912.

Electric hauling plant. Akt. Ges. Brown, Boveri, et Cie. 26130.

1913.

Electrical accumulators. De Sedneff. 1066.
Automatic electric supply systems. Leitner. 1413.
Fuses for use in electric circuits. Spagnoletti, Ltd., and Joyce. 3111.
Damping devices for measuring instruments. Breitinger. 3669.
Electric tachometers. Hopkins. 1671.
Electrodes for electric furnaces. Scott. 1723 and 1724.
Means of regulating arc furnaces. Scott. 1725.
Apparatus employed for wireless telegraphy. Chambers. 1777.
Electrical order transmitting systems. Graham & Rickets. 1829.
Dynamos. Vandervell & Midgley. 5014.
Submarine signalling apparatus. Marks. 5250.
Secondary batteries. Heap, and Chloride Electrical Storage Company. 6462.
Fuses for electric circuits. Siemens Schuckertwerke Ges. 6880.
Electric switches. Lundberg, Lundberg, Lundberg, & Pegg. 7085.
Material suitable for electrical insulation. British Thomson Houston Company. 8417.
Electric contact makers. Black. 8561.
Incandescent electric lamp. Giusti. 8568.
Prepayment automatic telephones. Breguet, and Frères Breguet et Cie. 8615.
Apparatus for electric lighting, heating, and ventilating of railway carriages. Ferguson & Johnstone. 9009.
Electric measuring instruments. Phillips & Smith. 13844.
Electric switches. Conner & Kahl. 14816.
Arrangements for producing electro magnetic oscillations. Ditcham and Grindell Matthews Wireless Telephone Syndicate, Ltd. 14927.
Measuring instruments for high frequency currents. Siemens Bros. & Co. 17126.
Electric starting device for internal combustion engines. Renault. 18252.
Electric transformers and welding and smelting apparatus. Mack. 19512.
Polyphase current motor starters. Voigt & Haeffner Akt. Ges. 19648.
Circuit arrangements for semi automatic telephone systems. Siemens & Halske Akt. Ges. 21766.
Contact breaker for magneto electric ignition apparatus. Union werke Mea Ges. Elektrotechnische Fabrik Eisenwerk. 23739.
Automatic regulating devices for electric distribution systems. British Thomson Houston Company, and McCarthy Jones. 25163.
Submarine signal receiving apparatus. Berger. 25207.
Arc lamps. A. W. Penrose & Co., and Owen. 26913.
Telephone exchange switch boards. Graham. 27751.
Arc lamps. Korting & Mathiesen Akt. Ges. 27878.

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TUESDAY, MARCH 10TH.

Aluminium ingot	86/-	per cwt.
,, wire, according to sizes, &c. ......from	112/-	,,
,, sheets ,, ,, ... ,,	112/-	,,
Antimony	£27/10/- to £29/10/-	per ton.
Brass, rolled	$7\frac{1}{4}$d.	per lb.
,, tubes (brazed)	$9\frac{5}{8}$d.	,,
,, ,, (solid drawn)	$8\frac{1}{8}$d.	,,
,, ,, wire	$7\frac{3}{8}$d.	,,
Copper, Standard	£64/-/-	per ton.
Iron, Cleveland	$50/4\frac{1}{2}$	,,
,, Scotch	$56/4\frac{1}{2}$	,,
Lead, English	£20/7/6	,,
,, Foreign (soft)	£20/2/6	,,
Mica (in original cases), small	6d. to 3/-	per lb.
,, ,, ,, medium	3/6 to 6/-	,,
,, ,, ,, large	7/6 to 11/-	,,
Quicksilver	£7/10/-	per bottle
Silver	$26\frac{13}{16}$d.	per oz.
Spelter	£21/10/-	per ton.
Tin, block	£172/10/-	,,
Tin plates, I.C.	13/3	per box.
Zinc sheets (Silesian)	£24/15/-	per ton.
,, (Stettin; Vieille Montagne)	£25/2/6	,,

Examinations for Smoke Inspectors.—Examinations for smoke inspectors have been established by the Royal Sanitary Institute, and are arranged to be held in several centres in 1914. The syllabus includes those subjects with which it is necessary that smoke inspectors should be cognisant in order to carry out their duties satisfactorily, and a theoretical as well as a practical knowledge of the administrative duties is required in order to pass the examination.

The Mechanical Engineer.

AN ILLUSTRATED WEEKLY JOURNAL Vol. 33 No. 843.

Edited by
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Telegrams: "Scientific," Manchester.
Telephone No. 6055 City.

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The Revocation of Patents.

THE working of the patent laws has always provided more or less thorny matters of dispute. This is to some extent inevitable with any law that seeks to regulate monopoly and adjust the claims of those who possess it with the claims of those outside, *i.e.*, the rest of society who grant the monopoly. Such a grant is not an ideally perfect method of rewarding an inventor for the benefits he confers upon fellow-men, but it is the best practical method so far discovered for inducing an inventor to reveal or make "patent" the outcome of his ingenuity or experiment so that it becomes eventually a portion of the common stock of human knowledge. The duration and extent of such a monopoly, and the method of procedure to secure it, differ in different countries, though the principle of granting patent rights to inventors in return for prospective benefits to the State is common to all. The State, in this country at all events, has not always regarded the relations between the patent department and inventors as a question of ethics so much as a means of raising revenue, and patents were granted to all and sundry provided they paid the fees, regardless of the mutual obligations which led to its establishment in the first instance. Patents were granted for anything or to anybody, were they Britishers or foreigners. The fact that the object of the grant of a patent monopoly was to benefit the trade and industry of a country ultimately was lost sight of, and, under the regulations, it was possible for serious injustice to be inflicted on British subjects, since, under our procedure, patents could be secured and so worked as to prevent anyone taking up the manufacture of the patented article in this country. In connection with the chemical and dyeing industries this objectionable action became so flagrant that in 1907 an amending Act was passed by Parliament to correct this abuse. Section 27 of this Act provides that any person may at any time after four years from the date of the patent apply to the Comptroller for re-

revocation upon the ground that the patented article or process is manufactured or carried on mainly outside the United Kingdom. Though this section does not differentiate between the nationalities of patentees, its intention was to prevent the holding of restrictive monopolies by foreigners who used their British patents merely as a means of stifling competition in this country without employing British labour or stimulating British enterprise, and which in certain directions, as we have stated, had become a scandal. It is always much easier, however, to recognise a social wrong than it is to devise a legal remedy, and it would appear that the effects of the Act are not fulfilling the intentions of its promoters, and considerable dissatisfaction is felt in consequence. This has found expression at the meetings of various Chambers of Commerce, and at the annual meeting of the association a resolution was passed calling for further amendment on the ground that a legal interpretation which threw the onus of proof that a patent was not being properly worked on to the applicant for revocation and not on to the patentee had practically rendered the Act a dead letter. The resolution, however, was not accepted unanimously, and there is no doubt difference of opinion exists as to whether the onus of proof should rest with the patentee or with the applicant. There is something to be said on both sides. On the one hand, a patentee might be harassed if it is open to any common informer to institute frivolous applications for revocation, and, under the pretence of enquiry, be called upon to reveal information which he would prefer to keep to himself on ordinary business grounds. On the other hand, to secure sufficient evidence to establish a primâ facie case against a delinquent patentee who is under no obligation to reveal anything might be so expensive and troublesome as to practically deter anyone from instituting revocation proceedings. Be the cause what it may, a big decline has occurred in revocation cases. In 1908, the year after the Act was passed, 15 applications for revocation were made. Of these, 2 were abandoned, 2 revoked, and 11 were left pending. In 1909 there were 55 applications, of which 27 were abandoned, 11 had revocation granted, while 5 were dismissed. In 1910, the year following the decision by Mr. Justice Parker which threw upon the applicant instead of on the patentee the onus of proof, only six applications were made, of which three were abandoned, one was revoked, one was dismissed, and one remained pending. In 1911 the applications numbered only five, and of these, revocation was granted in two cases. In 1912 the applications had dwindled to three, in one of which the patent was revoked by consent, the second was withdrawn, and the other left pending. It will be obvious from a glance at these figures that whatever the cause, the applications for revocation have practically dwindled to zero. It may be that there has ceased to be justification for such action, though the associated Chambers of Commerce, judging from their attitude, do not apparently take this view, or it may be that the casting of the onus on to the applicant has prevented the institution of frivolous proceedings, of which the figures for 1909 afford some evidence, seeing that 27 out of the 55 applications were abandoned. The drop from 55 to 6 applications in the following year is certainly striking, and the extent to which it is due to the suppression of frivolous cases or to the difficulty and expense of establishing them is not clear. Possibly both causes may be operative. There is no reason, however, why the intentions of the Act should not, as far as possible, be carried out, and it may be that in so far as any real injustice does exist it may be possible to largely remedy it, as the President of the Board of Trade informed a deputation from the Commercial Committee of the House of Commons, by modifying the rules under present powers.

STORAGE-BATTERY MOTOR-CARS ON GERMAN STATE RAILWAYS.

Some interesting particulars of the storage battery motor-cars in use on the Prussian-Hessian State Railways are given in an article by Mr. Weyand, member of the Board of Works, Berlin, in the January Bulletin of the International Railway Congress. The first cars put into operation on these railways were propelled by steam, but they never proved popular with the passengers. In 1906 designs were prepared and orders were placed for two steam cars, six storage battery cars, and one gasolene-electric car. Tests were subsequently made with the three types, when it was found that the storage battery cars gave the best results, and, as a consequence, their use has since been extended more than any of the other types. According to Mr. Weyand, there were in use on January 1st, 1913, 137 storage battery cars, 10 gasolene-electric cars, and 5 steam cars, representing a total cost of more than £500,000. Under construction, there were 39 storage battery cars, 6 gasolene-electric cars, and 2 Diesel-electric cars. The existing 152 cars ran regularly on 180 separate sections of a total length of about 3,077 miles; the total per week averages about 14,170 car miles. There are 53 stations and substations at which the storage battery cars are charged. The leading idea in the introduction of these motor-cars was not the desire to reduce operating costs, which has frequently induced minor and financially weak railways to try motor-cars, but the intention to improve transportation in certain particulars. Yet the financial results were by no means unsatisfactory, and fully satisfied expectations from the very start. Overcrowding of the motor-cars is avoided by adding trailers in suitable cases.

A question of great importance as regards the reliability of storage battery cars is the maintenance of the batteries. The battery requires careful, constant, and expert attention. This fact was fully recognised when storage battery cars were introduced, and with one exception — for purposes of experiment — the maintenance of the batteries was let by contract to the manufacturers who supplied the batteries, whose interest in keeping the cars ready for service coincides with that of the railway. The good results of this measure are proved by six years of collaboration, free from troubles of all kinds. It probably is not exaggerating to state that the quick development of storage battery car traffic on the Prussian-Hessian State Railways is due to the great reliability these cars have been proved to possess, which is above all due to this method of settling the maintenance question. The future will show whether it will later on become possible, both technically and economically, to leave the maintenance completely to the railway employés. Tables I. and II. give the approximate results of operation of these storage battery cars.

Table I.

	Mean.	Maximum.	Minimum.
Annual mileage per car	25,890	39,725	16,094
Average number of passengers carried, number	27·4	55·0	15·3
Cars at work, in per cent.	77·8	of all car days	—
Cars in reserve, in per cent.	9·0	—	—
Cars under repair, in per cent.	13·2	—	—
Receipts per car mile	11·95d.	27·8d.	7·3d.
Expenses per car mile	10·00d.	16·0d.	7·3d.

The three chief items of Table I., mean mileage per car, mean number of passengers carried, and mean expenses per car mile, very closely approximate the estimates worked out before the cars were introduced. It is worth noting, in view of the fact that it is often stated that storage battery cars are only capable of poor utilisation, that the annual mileage of the cars amounted in individual cases to nearly 39,768 miles, a value which certainly cannot be considered low. As regards the mean number of passengers carried, it may no doubt be assumed, leaving newly-instituted services out of

consideration, that there will be a gradual increase, resulting both from the growth of traffic generally, and from the stimulating influence of the more frequent services which motor-cars in many instances provide.

TABLE II. *Division of Expenses.*

	Mean.		Maximum. Pence per car mile.	Minimum. Pence per car mile.
	Pence per car mile.	Per cent. of total expenses.		
Interest and amortisation of stationary installation and of cars......	2·60	26·60	5·70	1·60
Changing current	2·50	25·15	4·80	1·50
Cost of heating	0·25	2·10	0·35	0·05
Cost of staff............	2·00	20·25	3·20	1·30
Operating expenses (lubrication, cleaning, attendance at charging station, &c., stores, and wages)	0·35	3·55	0·85	0·03
Maintenance of batteries, including amortisation	1·85	18·40	2·50	1·70
Maintenance of cars and their equipment, excluding batteries	0·45	3·95	1·05	0·03
Total	10·00	100·00		

Using batteries of the same kind, cars are now being built for ranges of 130 km. and 180 km. (80·8 and 111·8 miles). In cases where this is an advantage, the batteries of existing cars having a range of 100 km. (62·1 miles) are converted, when it is necessary to renew the plates, so as to have a range of 130 km. (80·8 miles). It is self-evident that the weight of the batteries, which forms an important part of the total dead weight of accumulator cars, is still further increased if the range is increased. Great attention is hence devoted to attempts to reduce the weight of the batteries.

In order to meet the desires of the travelling public, deviations from the very correct principles that motor-cars should be as simple as possible, are permitted to the extent that in cases where a separate second-class compartment is provided, this is in future to be equal to second-class compartments of ordinary passenger trains as regards room, comfort, and quality of the equipment. A new arrangement of cars has also been introduced, namely, a two-axle car with driving axles, close coupled between the two halves of an ordinary duplex accumulator car. In this way room is obtained for mails and baggage, and also for a larger number of passengers. Such an arrangement consists of three parts, and accommodates 16 second-class passengers, 40 third-class passengers, and 62 fourth-class passengers (including standing room for 8); that is, a total of 118 passengers, and can also carry mails and luggage. Thus it is very suitable for replacing steam trains where the traffic conditions are of this kind. Where it is a question of long distance, these three-part trains are fitted also with lavatories. Three of these three-part trains are equipped with the new batteries described above, so that they have a range of 180 km. (111·8 miles). A similar train, to carry 167 passengers, but neither luggage nor mails, has also been introduced. Whether such large train units consisting of accumulator cars will give economical operating results remains to be seen.

ELECTRICALLY-CONTROLLED PRONY BRAKE.

A SINGLE prony brake, when used to absorb energy from a rotating flywheel, will not ordinarily maintain a constant engine speed even when frequently adjusted by hand. This is due largely to the change in the coefficient of friction between the flywheel and the brake shoe caused by heating, presence of oil, and by varying conditions of lubrication. An electrically-controlled dynamometer which will automatically maintain a constant engine speed, even under the conditions mentioned above, was described by Mr. Nathan C. Johnson at the annual meeting of the Society of Automobile Engineers recently held in New York, and we are indebted for the following particulars to our American contemporary, "The Electrical World."

The principle of the modified prony brake is shown in Fig. 1. Instead of manually adjusting the grip of the brake band, the latter is automatically controlled by an electro-magnet which acts through a toggle joint. The exciting current for this magnet is furnished by a small magneto belted to the engine shaft. If the engine speeds up slightly, the magneto drives more current through the electro-magnet, thereby increasing the pressure on the brake band and restoring the engine speed to normal. The brake arm rests on a knife edge on the scale platform, and a counter

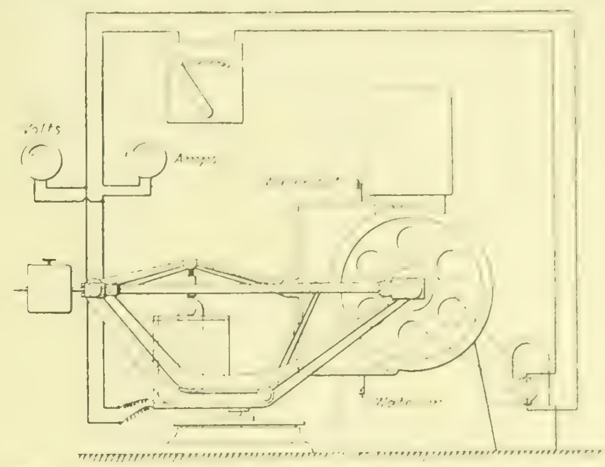


FIG. 1. ELECTRICALLY-CONTROLLED PRONY BRAKE WITH SOLID SHOE.

weight overcomes the tendency of the brake shoe to fall inwardly against the flywheel. The thrust of the brake shoe caused by friction with the flywheel is transmitted in a direct line to the knife edge by a compression member. No strains are caused in the engine shaft by using this brake as the thrust of the shoe is taken up entirely by bearings on each side of the flywheel.

In the circuit between the magneto and electro-magnet are an adjustable resistance and a wattmeter or a voltmeter and ammeter. By varying the resistance the brake load can be changed and read on the scale beam as usual.

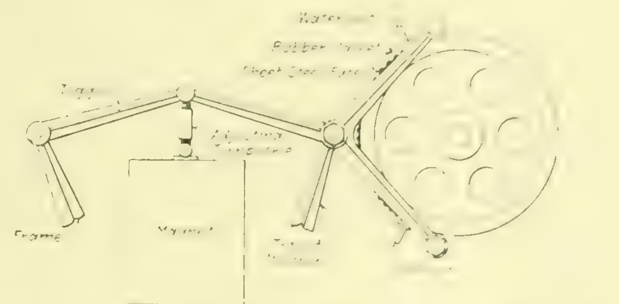


FIG. 2. FLEXIBLE PRONY BRAKE SHOE [illegible]

The volt-ampere readings, or watts, and the internal losses in the magneto should be added to the brake readings to obtain the total power developed by the engine.

Experiments conducted at Cornell University with this apparatus have shown that there is no perceptible variation in the speed or load. If the brake shoe is made flexible, as shown in Fig. 2, it will fit flywheels of different diameters, and the heat caused by friction will be radiated faster than if a solid shoe is used. By placing two water-cooled shoes on opposite sides of the flywheel the radiating surface can be still further increased.

Fatal Explosion at a Foundry. During the casting of a chilled ram at the works of the Brightside Foundry and Engineering Company, Sheffield, on Saturday last, an explosion occurred, which resulted in a column of molten metal being showered on to a gang of workmen, six of whom were seriously burnt, one so severely that he subsequently died. The cause of the accident is at present not known.

BOOK REVIEWS.

Handbook on the Steam Engine. By Herman Haeder. Translated from the German (with additions) by H. H. P. Powles. Fourth edition. London: Crosby Lockwood and Son. 7½in. by 5¼in.; 522 pp. Price 7s. 6d. net.

This excellent manual of formula and sketches illustrative of steam-engine practice has evidently met with an appreciative circle of readers in this country, a success at which we are in no way surprised, as it is so essentially practical and at the same time is typically German as regards its thoroughness, some idea of which is conveyed by the fact that it contains over 1,000 illustrations of working parts, most of which are drawn to scale, while many are accompanied with tables which permit of the adaptation of the sketches to other sizes. It is impossible within the scope of a short notice to summarise the contents, but we may give some indication of its scope and merits by saying that it is a book which no engine maker's drawing office can well afford to be without, and which every draughtsman will find to be a useful companion. In the edition just issued the work has been supplemented with an appendix of some 64 pages which is devoted entirely to steam turbine practice.

* * *

The Mechanical Engineer's Pocket-book of Tables, Formulæ, Rules, and Data. By the late D. K. Clark, M.Inst.C.E. 1914 edition, revised and enlarged by H. H. P. Powles. London: Crosby Lockwood & Son. 6in. by 4in.; 708 pp. Price 4s. 6d. net.

Tremendous changes have taken place in mechanical engineering since the late Mr. Clark first devoted his attention to the compilation of this little handbook, and it is a pleasure to note that, notwithstanding the innumerable changes that have been necessary in consequence of the evolution of engineering practice, this friend of our early days still retains a place in popular esteem, though its price probably handicaps it rather seriously in its competition with later and more cheaper rivals. Nevertheless, it contains some distinct features, and, having regard to the cheapness generally of modern literature it will probably continue to hold its position alongside its rivals. The editor's work has been well done, and his efforts have been worthily seconded by the publishers in the way of good paper and printing.

* * *

The Inventor's and Patentee's Year Book for 1914. By William H. Taylor. Manchester: The Dexter Press, Ltd. 7½in. by 5½in.; 736 pp. Price 7s. 6d. net.

So many books have been written for the instruction of inventors and patentees with regard to patent procedure, and practice is now so generally crystallised by case law and Acts of Parliament, that there would seem to be little scope for further new literature. Every patent agent, however, regards himself as a special expert, and in this respect the author is no exception to the rule, though he is able to claim a longer and wider experience than most of them, more particularly as regards mechanical and textile work. The author evidently formed a generous conception of his task, for the book is a general treatise on the subject of inventions, patents, and trade-marks, both here and abroad. Considerable time and trouble have been spent in compiling the information presented, and, as a general guide on the subject, we have every pleasure in recommending it, not only to inventors generally, but to patent agents who do not aspire to the honours of authorship.

* * *

Wireless Telegraphy, a Handbook for the use of Operators and Students, by W. H. Marchent; 154 illustrations. London: Whittaker & Co. 7½in. by 5¼in.; 238 pp. Price 5s. net.

The wide adoption of wireless telegraphy for international and maritime communication has not only led to its systematic registration as a subject of study in teaching institutions, but to its practice by a wide field of amateurs, so that a somewhat extensive circle of readers has arisen, and with it a corresponding demand for elementary technical literature. The book under notice is intended primarily for the use of those engaged in practical radio-telegraph work, as well as for students who possess some electrical knowledge. The first portion deals with the production and radiation of electric waves generally and with the apparatus and adjuncts which go to make up a wireless station, following which are descriptions of the principal systems employed, methods of signalling, codes, &c. The book is well illustrated and clearly written, and, within its range of treatment, admirable. We have pleasure, therefore, in recommending it.

BOOKS RECEIVED.

The Co-operation of Science and Industry. By S. Roy Illingworth, with foreword by Sir Boverton Redwood. London: Chas. Griffin & Co. 1s. 6d. net.

Engineering Workshop Exercises for Technical Students and Apprentice Engineers. London: Whittaker & Co. Price 2s. net.

Examinations in Science and Technology, 1913. Examination papers and reports of examiners. London: Eyre & Spottiswoode. Price 9d.

Transactions of the Liverpool Engineering Society. Vol. XXXIV. Edited by T. R. Wilton, M.A., Assoc.M.Inst.C.E. Published by the Royal Institution, Colquitt Street, Liverpool.

The Textile Journal. Vol. V., No. 1. Edited by T. W. Fox and J. Hübner. Manchester: St. Mary's Parsonage.

FREE CARBON IN IRON AND STEEL.

At a recent meeting of the Sheffield Society of Engineers and Metallurgists held at Sheffield, Dr. W. H. Hatfield, in a paper entitled "A study of the conditions under which free carbon appears in steels, cast iron, and malleable cast iron," said that it was necessary to cover broad ground owing to the fact that free carbon was a phenomenon found in products widely distributed amongst the carbon series of alloys. He described the appearance of free carbon in steels as one of the common troubles with which steel makers were called upon to deal, and which must be avoided. The precipitation of free carbon in cast iron was, however, an essential reaction which, in foundry irons in particular, invariably took place in the cooling down of the material from casting temperatures, and was responsible for the ease with which such material could be machined. In malleable iron the precipitation became all-important, it being the means by which hard, brittle, white cast iron was rendered malleable during the process of heat treatment. The lecturer endeavoured to treat the whole of the iron carbon alloys, whether pig irons or steels, from a general standpoint, and it was insisted that the alloy in every case was primarily one of iron and steel carbide, and the theory upon which he worked was that the carbon was in solution as carbide, and therefore must come out of the solution as such. He claimed, therefore, that it was obvious that the appearance of free carbon was invariably preceded by the appearance of free carbide, which subsequently broke down into the free state. Discussing the problem of black steels, sometimes met with in works practice, he confirmed data on the subject which had been supplied by Dr. Arnold and Dr. McWilliam, in which it was pointed out that it was only in super-saturated steels that the precipitation was likely to be observed. He (Dr. Hatfield) made one reservation, however, as to that view, since he had never met with the phenomenon in purely iron carbon steels which did not normally present a micro structure in which free cementite appeared. It was found that when the annealing carbon was produced by simple heat treatment alone there was a formation of micro structure, consisting of a matrix of pearlite in which were seen the membranes of excess carbide. From his own researches in this field he would suggest that in the instance of precipitation in such steels during annealing the whole of the cementite would possibly not be in solution at the high temperatures.

"Lusitania's" New Speed Record.—The Cunard liner "Lusitania" has established another world's record. She left New York for Liverpool on Tuesday, the 10th inst., and between Thursday noon and Friday noon steamed 618 knots at an average speed of 26·70 knots an hour, beating the previous record of 614 knots held by the "Mauretania."

THE INSTITUTE OF METALS.

THE annual general meeting of this institute was held at the Institution of Mechanical Engineers, Storey's Gate, Westminster, S.W., on Tuesday and Wednesday last. On the Tuesday the report of the Council was presented and the inaugural address of the new president, Engineer Vice-Admiral Sir H. J. Oram, K.C.B., F.R.S., was delivered. On the following day a number of interesting papers were read, abstracts of which are given below:—

Bronze.—In this paper, by Mr. John Dewrance, M.Inst.C.E., the author drew attention to the desirability of modifying the composition of bronze, with the object of preserving its strength when used for high-pressure and superheated steam. The results of a large number of experiments were presented which go to establish the fact that the addition of a half of 1 per cent. of lead preserved the strength of the bronze up to 500°, and that without the lead bronze lost its strength at 350° Fah. The author suggested that as lead had this effect it was probable that further investigation might prove that some other ingredient might preserve the strength of bronze at even a higher temperature. It was also shown that oxygen in bronze did not reduce the strength within practical limits.

The Effect of Vanadium on the Constitution of Brass containing 50 to 60 per cent. of Copper.—The experiments described in this paper, by Mr. R. J. Dunn, M.Sc., and Mr. O. F. Hudson, M.Sc., were carried out with the object of ascertaining what, if any, was the effect of small quantities of vanadium on the constitution and structure of certain copper-zinc alloys, particularly with reference to the change which occurs at about 460° C. in those brasses containing the beta phase. A number of alloys containing small percentages of vanadium and inconsiderable quantities of impurities resulting from the reduction of pure vanadic acid by means of aluminium were tested thermally and microscopically. It was found that the critical point at 460° C. was only slightly affected by vanadium, 1 per cent. raising it not more than 10° C. It was also found that the usual structure of brasses containing 50 to 60 per cent. of copper was not greatly modified by the presence of small quantities of vanadium. Thus the observation of Carpenter that 1 per cent. of vanadium caused the complete structural resolution of beta into alpha and gamma was not confirmed. Some of the alloys were subjected to prolonged annealing at temperatures just below 460° C., and the conclusion arrived at was that vanadium to the extent of at least 1 per cent. appeared to have no influence on the structural stability of the beta constituent of the copper-zinc alloys. The authors also considered that if any structural resolution of beta into alpha and gamma followed the addition of cupro-vanadium to brass the result probably was due rather to the relatively large amounts of aluminium usually present in commercial samples than to the small percentage of vanadium remaining in the finished brass. In an appendix a brief description was given of the method of analysis adopted.

The Quantitative Effect of Rapid Cooling upon the Constitution of Binary Alloys. Part II.—This paper, by Mr. G. H. Gulliver, B.Sc., is a continuation of one read before the Institute last March. The methods then explained are extended, so that the proportions of the constituents of a rapidly cooled binary alloy can be determined with a close degree of approximation, whatever the curvature of liquidus and solidus. Results were given for the more important alloys of the copper-tin and the copper-zinc series, and for the copper-nickel series. A formula had been devised for calculating the proportions of the constituents obtained with moderate rates of cooling when the liquidus and solidus were sensibly straight, and the results obtained from this for the lead-tin series were given.

The Influence of Nickel on some Copper-Aluminium Alloys.—The authors of this paper, Prof. A. A. Read and Mr. R. H. Greaves, M.Sc., investigated the influence of varying percentages of nickel on some mechanical and physical properties of the copper-aluminium alloys with 5 and 10 per cent. of aluminium respectively. Hot rolling and forging tests showed that apart from increased hardness, and the necessity of a higher rolling temperature, the behaviour on hot rolling of alloys with up to 7½ per cent. of nickel was identical with that of the pure copper aluminium alloys. Malleability and ductility were rapidly reduced by nickel in the 10 per cent. aluminium series, but with 5 per cent. of aluminium the presence of nickel increased the ductility, as judged by the wire-drawing tests. The main features of the tensile, hardness, and alternating stress tests, considered in conjunction with the microstructure, were briefly as follows:—

(1) *Alloys with 10 per cent. of aluminium.*—Nickel up to 10 per cent. in the chill castings gave increased maximum stress and yield point at the expense of elongation and reduction of area; 5 per cent. of nickel gave maximum hardness; 5 per cent. of nickel improved the annealed metal and diminished the detrimental effect of annealing on the 10 per cent. aluminium alloy. This composition corresponded to the limit of the alpha plus beta structure, increase of nickel above 5 per cent. being accompanied by the separation of a blue constituent in place of beta. The effect of quenching on these alloys was similar to that on the 10 per cent. aluminium-bronze, but became less marked as the nickel increased.

(2) *Alloys with 5 per cent. of aluminium.*—Both in the chill castings and annealed rods, nickel had little effect on the hardness, maximum stress, and yield point until 5 per cent. was present. The ductility, however, was greatly increased by 1 per cent. of nickel. With less than 5 per cent. of nickel the alloys consisted of a homogeneous solid solution; with more than 5 per cent. a second constituent separated on slow cooling, causing in the annealed rods a rapid increase in hardness, maximum stress, and yield point, with an accompanying diminution in elongation and reduction of area. The effect of quenching on the alloys with 5 per cent. of nickel and over was to retain the second constituent in solid solution and thus to increase the ductility, while the hardness, maximum stress, and yield point diminished. The rate of cooling need not be very great for air-cooled rods gave results which approximated to those of the quenched.

The presence of nickel made practically no difference to the specific gravity of these alloys; their melting points were raised, and conductivity for electricity greatly diminished. Corrosion by sea water was greatly reduced by the presence of nickel; there was no difference in behaviour between the annealed and cold rolled metal. All the alloys with 5 and 10 per cent. of aluminium and varying nickel behaved better both in fresh and sea water than either Muntz metal or naval brass.

First Report on the Solidification of Metals from the Liquid State. In this report, by Cecil H. Desch, D.Sc., Ph.D., presented to the Beilby Prize Committee, it was pointed out that the arrangement of crystal grains in a metal or alloy had usually been accounted for by growth of crystallites from independent centres. Against this, Quincke had proposed the hypothesis of foam cells. On this view, the liquid separated, immediately before crystallising, into two liquids, which arranged themselves to form a foam, and crystallisation then took place within the foam cells. Quincke had applied the hypothesis to the explanation of many of the properties of metals. Several recent writers had also sought to connect the cellular structure with the prismatic partitioning of cooling liquids by convection currents. Whilst this arrangement might possibly be traced in some metals when cast in thin sheets, it could not account for the structure of ingots or other large masses. The passage of metals in certain cases through an intermediate liquid-crystalline state had also been assumed, but not yet established. A review of the existing evidence suggested that several distinct cellular structures had often been confounded, and that a common origin had been assumed for structures which had a merely geometrical similarity. The effect of under-cooling, and the possibility of existence of two distinct classes of under-cooled liquids was also discussed, as well as the changes of volume which occurred during fusion and solidification. The determination of such changes was shown to be complicated by other factors, so that an increase in the external dimensions of a casting did not invariably represent an actual increase in the volume of metal. Lastly, the programme of experimental work now

in progress, with the object of testing and comparing the hypotheses mentioned, was briefly outlined.

First Report of the Committee on the Nomenclature of Alloys.—The Committee, consisting of representatives of the Institute of Metals, the Institution of Mechanical Engineers, the Institution of Electrical Engineers, the Institution of Naval Architects, the Institution of Engineers and Shipbuilders in Scotland, the North-east Coast Institution of Engineers and Shipbuilders, and the Society of Chemical Industry (chairman, Dr. W. Rosenhain, F.R.S.), presented a unanimous report, in which they recommend the adoption, first, of a systematic nomenclature in which alloys are denoted by the names of their constituent metals in English, arranged in increasing order of percentage present in the alloys. This systematic nomenclature is intended chiefly for scientific and other purposes where its precise character more than out weighs its cumbrousness. The Committee next recommend that a system of "practical" nomenclature should be set up, consisting of "practical" names which are to serve as every-day abbreviations of the systematic or scientific names. The definition of current practical names on this basis has so far only been attempted in regard to the two important terms "brass" and "bronze." The definition of "brass" adopted by the Committee is that it is to be used as an abbreviation of the words "zinc-copper," as employed in the systematic nomenclature; when employed alone it indicates that the alloys are pure zinc-copper. Where the presence of other metals is to be indicated their names are to be prefixed to the term, forming such words as tin-brass, aluminium-brass, manganese-brass, &c. Similarly, the term "bronze" is defined as an abbreviation for "tin-copper," as used in the systematic nomenclature, the definitions in other respects being identical as that for "brass." The Committee is not yet prepared to recommend definitions of further practical terms, but the two terms defined represent the most widely-used alloys, and their general adoption as thus defined would do much to remedy the state of confusion which exists at the present time. The Committee, therefore, appeal to all those interested in the progress of the industries and sciences connected with metals to use their best endeavours to support and carry out the recommendations of the Committee.

The Micro-chemistry of Corrosion. Part II. The A-Alloys of Copper and Zinc.—In continuation of their former work, the authors, Mr. Samuel Whyte, B.Sc., and Mr. Cecil H. Desch, D.Sc., had examined the effect of electrolytic corrosion on the A-brasses. The total corrosion was less than in the B-brasses, and there was less preferential removal of zinc. The alloy containing 1 per cent. of tin was at first more corroded than a 70:30 brass, but as time went on the corrosion was lessened, owing to the formation of a very tough layer of basic salts. The protective action of tin was attributed to this cause. One per cent. of lead did not retard corrosion, as the residual coppery layer was very open in texture, but an alloy with 2 per cent. of lead (70:28:2) became covered with a very firmly adherent layer. This alloy was much less corroded than any of the others examined. Brass condenser tubes, corroded during service, had a structure which might be exactly reproduced by the application of an external electromotive force. This point was proved by photomicrographs. The apparent differences depended on the rate of corrosion and the supply of oxygen. When corrosion was slow and the oxygen supply abundant, the spongy layer of copper was converted into oxide as fast as it was formed, but otherwise a metallic dezincified layer remained.

Muntz Metal.—In this paper, by Mr. J. E. Stead, D.Sc., F.R.S., and Mr. H. G. A. Stedman, the authors obtained a set of ½in. bars of pure Muntz metal for the purpose of the research, heated them in duplicate in a tube furnace electrically heated for 48 hours to various temperatures ranging between about 500° C. and 860° C., after which treatment one of the heated bars in each set was quenched in cold water, the companion bar being allowed to cool in air. The cold bars were then examined microscopically and tested mechanically. Other bars were heated for three months at about 430° C., and at 270° C., for 984 hours, and they were also tested and examined. The results appeared to dispose of the idea, held in some quarters, that Muntz metal could be burnt by high heating, and that quenching tended to soften brass, for while the annealed metal cooled in air had a tenacity of about 25 tons, the same material quenched from 812° C. had a tenacity of 29½ tons—an increase of about 4½ tons. The result of this research showed (1) that Muntz metal should not be annealed at temperatures between 750° C. and 800° C., as this was a range of danger, but it might be heated above 800 C. without destroying its good quality; (2) that it was made homogeneous and could be hardened to a considerable degree by heating to and quenching from above 800° C.; (3) that the maximum degree of softness was obtained by long heating at the temperature of melting zinc, about 430° C.; (4) that Muntz metal was very slightly oxidised by annealing even at 800° C., and that the scale produced on the surface consisted of zinc oxide free from copper. The final part of the paper was devoted to a description of methods of tinting brasses so as to reveal their structure, and to the effect of hard drawing in leading to fractures in Muntz metal during service.

CO-PARTNERSHIP AND PROFIT-SHARING.

The Labour Department of the Board of Trade have issued a report on profit-sharing and labour co-partnership schemes in existence abroad. According to this France has a larger number of schemes than any of the other countries, and many of them are of very long standing. Regarded as a whole, these schemes differ in many respects from the English schemes, having their greatest developments in a totally different class of undertaking. The group in which profit-sharing has extended most widely is that of insurance companies and banks. Mines and quarries, railways and tramways, and metal, engineering, and shipbuilding firms are also represented. The typical French system is that of capitalising the bonus, and one method is of converting the accumulated bonuses into a pension for the employé on retirement, and also leaving something for the widow and children after his death. In Germany profit-sharing has made little progress, and many of the schemes introduced have been short-lived. Thus, of 54 schemes in existence in 1878, only 9 remained in 1901, and at present about 30 schemes are known to be in existence. The 21 undertakings for which particulars are available employ only 15,000 or 16,000 persons, and about one seventh of the number employed under the profit-sharing conditions in the United Kingdom. The profit-sharing schemes in Holland and Switzerland are mostly small. In the United States only about 25 or 30 firms practise profit sharing and co partnership, and most of these started their schemes only within the last ten or 12 years, not dating further back than 1886. On the other hand, the number of workpeople employed is relatively large, as many of the firms which practise profit sharing are vast corporations employing thousands of workpeople. On the whole, says the report, it would appear that profit-sharing is not regarded with very great favour in the United States; the principal reasons stated being, first, the attitude of the trade unions, and, secondly, the preference of employers for other means of improving the position of their workpeople. As regards the British dominions, it would appear that profit-sharing, as understood in this country, has scarcely obtained any foothold in Australia and New Zealand or in South Africa. It has made but little more progress in Canada, and one of the principal schemes which formerly existed has been abandoned.

Structural Steelwork.—At a meeting of the North-western Section of the Junior Institution of Engineers on Friday evening, the 6th inst., a discussion on "Structural Steelwork" was opened by Mr. F. Briggs. Dealing with steel frame buildings, he pointed out that the first instance of this type was the Crystal Palace; and the latest in this district, the Calico Printers' Association Building in Manchester. Rapidity of erection, the possibility of commencing to sheath the framework from the top and so protect the workmen and inside of the building from the weather, being able, if necessary, to work on all floors at the same time, the great height to which they could be carried (900ft. in some instances) were some of the many advantages of this class of building dilated upon by the speaker. Complaint was made of antiquated building by-laws blocking the path of progress in some districts.

LIQUID FUEL.

AT a meeting of the Institute of Marine Engineers on Monday, March 9th, a paper was read by Mr. J. Veitch Wilson on "Liquid Fuel," the hon. secretary, Mr. James Adamson, presiding. Mr. Veitch Wilson, in the course of an interesting historical retrospect, said it seemed reasonable to suppose, in view of the fact that so much petroleum had been found by spontaneous exudations and accidental discoveries, that the world was saturated with oil, and that by systematic investigations, supplies were likely to be discovered in every habitable quarter of the globe. The world's production of crude petroleum showed a steady advance each year from 264,249,119 barrels in 1907 to 351,178,236 barrels in 1912, and he understood that the figures for 1913 showed an advance of 10 per cent. over those of 1912. After dealing with the origin and constituents of petroleum, and describing early and recent devices for its utilisation as fuel, the author expressed the opinion that the full benefit in the use of oil was not to be derived from its substitution for coal for steam-raising purposes, but from the general adoption of the internal-combustion engine instead of the steam engine. Paraffin, which was practically free from oxygen, gave 20,251 heat units; while alcohol, which contained a high percentage of hydrogen, gave 12,593 units, and olive oil 17,482 units. But while it was apparent from these figures that the presence of oxygen reduced the calorific value of oils as fuels, it must be equally recognised that its presence promoted combustion and reduced the tendency to smoke with production of soot or carbon. Many vegetable and some animal oils might be burned in open lamps without smoke, while it was impossible to burn paraffin or petroleum under such conditions on account of the dense volumes of smoke they gave off. He thought, therefore, he was justified in saying that those engineers were in error who objected to the use of vegetable oils, pure, or mixed with mineral oil, as lubricants for internal-combustion engines for fear of the carbonaceous deposits which, they said, these oils were liable to produce. The author then described the various products obtained from petroleum suitable for different types of engines, and specially called atention to the ambiguous use of the expression "crude oil," which might denote either oil containing all its dangerous fractions or oil from which these have been removed by distillation. The paper concluded with tables showing fuel values, thermal and commercial.

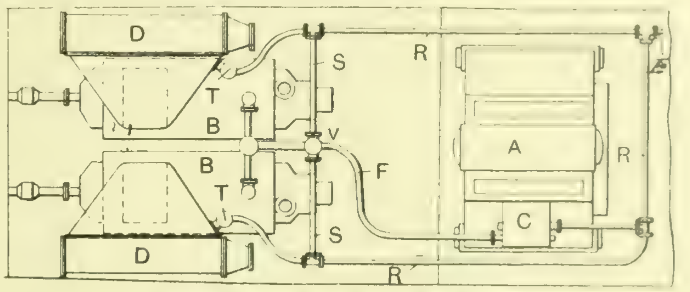
In opening the discussion which followed, Mr. F. M. Timpson said it was peculiar, in view of Mr. Veitch Wilson's remarks, that more mineral oil than vegetable oil was used for internal-combustion engine purposes. The mineral oils were found to be very satisfactory both for light and heavy engines. Mr. J. C. Williams considered that the question of suitability largely depended upon the manner in which the oil was introduced. The lubricating oil was put in as a lubricant, and therefore did not burn so quickly, with the result that it carbonised. Any oil introduced under those conditions would give the same result. Mr. J. Clark said the proper mixture of the air supply had a great effect upon the production of smoke, and many oil fuels produced smoke if this was not carefully watched. Mr. F. O. Beckett said the introduction of the internal-combustion engine opened up a problem for metallurgists to make a metal which would withstand the exceptional heat. Mr. Duncan Barr referred to methods of disposing of the tarry residue of a gas-producer plant. Mr. J. Shanks said he understood it was not possible in Diesel engines to introduce the lubricating oil with the fuel oil. The improvements effected in the steam engine in recent years had made it impossible for the internal-combustion engine to gain a footing on the ground of economy, but when oil became cheaper in price marine engineers were prepared to take charge of the internal-combustion engine and run it as successfully as they did the steam engine.

In replying, Mr. Veitch Wilson said his experiments had proved that fatty oils were not responsible for deposits in the engine. Troubles with deposits or gumming in gas engines were generally overcome by the use of a vegetable oil, and this course was invariably adopted and recommended by the late Sir William Crossley and other well-known makers of gas engines. With regard to the late Dr. Diesel's recommendation of mineral oil for the Diesel engine, this seemed inconsistent in view of his recommendation of his engine because it could use pure vegetable oils.

STEAM TURBINE INSTALLATIONS FOR SHIPS.

IN the case of installations of steam-driven machinery which include as elements steam turbines and auxiliary steam engines, wherein exhaust steam from the auxiliary machinery is utilised for doing work before entering the condenser, it has been proposed to pass the exhaust steam from reciprocating steam engines first through a minimum pressure boiler or auxiliary generator and then, together with the steam generated in such boiler, through a superheater heated by the waste gases of this boiler before being led to the steam turbine, and it has also been proposed to supplement at will the power developed by main reciprocating steam engines by utilising the exhaust steam of such engines, after passing it through a superheater, in a high-speed turbine driving a polyphase electric generator, the current from which drives an electric motor mounted on the shafts of the main reciprocating engines.

In the arrangement under notice, which has been patented by Mr. A. F. Yarrow, Campsie Dene, Blanefield, Stirlingshire, the exhaust steam from the auxiliary machinery of the steam installations of ships working on the closed exhaust system (according to which the exhaust steam from all the engines, whether condensing or not, is returned directly or indirectly to the boilers) is taken directly to a heater or superheater wherein its temperature is raised by heat derived either from the furnace gases or from the live steam of a high-pressure steam generator, or from a separately fired heater independent of the steam generating plant, or from the exhaust gases of an internal-combustion



STEAM TURBINE INSTALLATION FOR SHIPS

engine, should the installation comprise such an element, and thence passes to the low pressure side of the main propelling turbines of the system. The exhaust connections from the auxiliary machinery are such that heated or superheated exhaust steam only can be delivered to the main turbines from the auxiliary machinery, or the exhaust steam from the auxiliary machinery can be delivered to the main turbines without passing through the heater, or a mixture of heated and non-heated exhaust steam can be delivered to the turbines.

One arrangement is shown diagrammatically in the accompanying cut, wherein A represents one of the boilers which provide steam for the main propelling turbines B B and for the auxiliary machinery of the vessel. R S represents the exhaust pipe connections from the auxiliary machinery to the steam turbines B and condensers D, T being automatic or shut-off valves controlling admission of exhaust steam to the condensers. A heater C is provided within the furnace casing of one of the boilers A, and this heater is connected on the one hand with exhaust steam pipe R, and on the other hand with a pipe F leading to a valve V, and thence to the low-pressure side of the propelling turbines B. As shown, the valve V controls the supply of the exhaust steam, whether heated or not, from the auxiliary machinery to the main turbines, the valve being of such a character that either heated exhaust steam only from pipe F can be delivered to the main turbines from the auxiliary machinery, or the exhaust steam from the auxiliary machinery can be delivered through pipes R S to the main turbines without passing through the heater, or a mixture of heated and non-heated exhaust steam from pipes F R S can be delivered to the turbines.

POWER ECONOMICS FOR INTERMITTENT LOADS.*

By E. IVOR DAVID, A.M.I.E.E.

The reciprocating steam engine, by virtue of its elasticity and ease of control, has for many years been considered the only prime mover suitable for intermittent or reversing loads, but its position is now being assailed on all sides. With the exception of the piston type steam engine, the available prime movers, including gas engines, oil engines, petrol engines, water and steam turbines, are not easily reversible, and therefore not directly applicable to loads requiring to be reversed frequently. It is necessary to provide some means of transmission or transformation, and electricity has proved most suitable for this purpose. Various hydraulic devices have also been tried, notably the Föttinger, for ship propulsion. The steam turbine is particularly suitable for the generation of cheap electric power, and its high overload capacity renders it especially suitable for loads of the most fluctuating character.

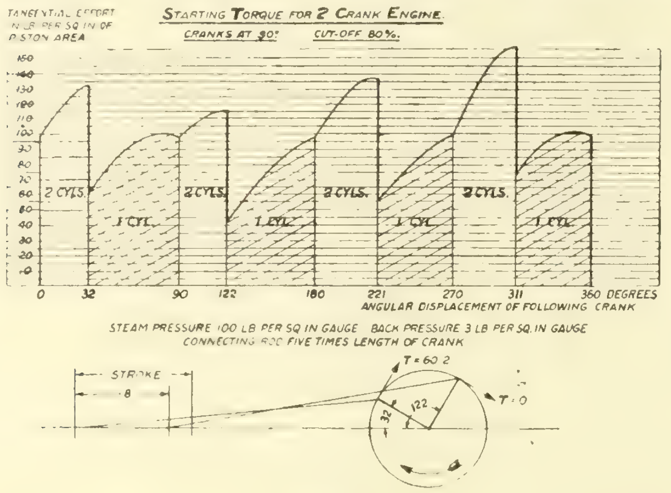


Fig. 1

The first cost of an equipment using electricity as the means of transmission is usually higher than that in which the prime mover is directly applied to the load, but the total working costs are generally lower. The reason for this is not at first apparent, but it will be seen that though the steam engine is suitable for dealing with variable loads, it is very uneconomical, especially when it is required to operate against heavy starting torques. An engine working against an intermittent or reversing load has to overcome not only the ordinary resistance or load, but also the inertia effects due to acceleration and deceleration of the moving parts, which in some cases exceed the net load. In the case of winding engines where the moving masses are heavy, or reversing rolling mill engines, where the rate of acceleration is high, the starting effort is the limiting feature to be considered in the design.

Consider first the case of winding engines for mines. A winding engine is required to raise a certain weight of material from a certain depth, at a certain maximum rate per hour. The ordinary type of steam engine employed for this purpose has two cranks, and two high-pressure cylinders, with occasionally two low-pressure cylinders in tandem with the high-pressure. The cranks are generally arranged at right angles, and Fig. 1 shows that there are four periods in a revolution, where one cylinder only is operative. For economy, it is required that the steam should be cut off early in the stroke, but if cut-off takes place earlier than half-stroke the engine will not start at any of four points in a revolution. The usual cut-off at starting is ·8 to ·9 of the stroke for winding engines. The diagram gives the tangential effort per square inch of piston area, assuming an initial pressure of 100lbs. per square inch gauge, 3lbs. per square inch back pressure, cut off at 0·8, and a connecting rod five times the crank length. The average tangential effort over a revolution is 119·23lbs., and the minimum 42·5lbs., the ratio of average to minimum is therefore 2·81 to 1.

The starting load on a winder consists partly of the static load due to unbalanced weights on the rope, and partly of the dynamic load due to the effort required to accelerate the masses of the gear and the load. The minimum engine starting torque must be capable of overcoming the former, together with the various frictional resistances, and also imparting a slight acceleration to the masses. An engine of sufficient size to start its load under all conditions would therefore be 50 to 100 per cent. larger than necessary once it attained sufficient speed to carry it over the low torque periods. Owing to the excessive torque of the engine, once the starting difficulty is overcome, the acceleration of the moving masses and the resulting stresses produced on the machine parts are high. The late cut-off results in very uneconomical use of the steam, and various automatic devices have been introduced, to effect an earlier cut-off once the machine has attained a reasonable speed. These have been more or less successful, but their range is limited with ordinary Stevenson's link motion, as the ratio of expansion for satisfactory working is not more than 2; earlier cut-off produces excessive wire drawing and back pressure. In more modern engines, with Corliss or drop-valve gear, variable expansion is usually adopted, controlled by some form of governor, and a wider range is possible.

A normal wind for a mine hoist may be divided into three periods—acceleration, full speed, and braking. During the acceleration period, energy is imparted to the masses of the winder and load, and for economy should be utilised during the braking period. To effect this the steam should be shut off at some point during the wind, such that the accumulated energy of the moving masses is sufficient to carry out the remainder. This ideal condition is seldom possible, as the time available for a wind is usually so short that high rates of accelerations and retardations are necessary to keep the maximum speeds within the limits permitted. To obviate unnecessary wear and tear of the brake gear, the winder is often retarded under reversed steam with a slight touch of the brakes as the set comes to rest, and thus the greater part of the energy imparted to the moving masses is wasted. The curves given in Fig. 2 show the

Table 1.—*Tests of Steam and Electric Winding Engines.*

Name of Plant.	Capacity of Plant.			Load during Test.			Kw. hours per Shaft h.p. hour.	Lbs Steam per Shaft h p hour.	Load Factor per Cent.
	Tons per hour.	Winding Depth. Ft.	Shaft. h.p.	Tons per hour.	Winding Depth. Ft.	Shaft.			
Steam Winding Engines:									
Schurbank u Charlottenburg	130	2620	392	139	1980	313·8	—	36 3	80
Julia	124	2620	374	121	1340	187	—	59·3	50
Heine u. Amalie	108	2230	277	89	1815	185·6	—	54·5	67
Wilhelmine Victoria	138	2620	415	120	1990	274·5	—	46·6	66·2
Westerholt	113	2620	340	144	1750	288·4	—	29·4	85
Electric Winding Engines:									
Deutscher Kaiser	148	2300	390	84	1240	119·6	2·29	36·6	30·7
Reinelbe	126	3280	473	189	1210	262·7	1·67	26·7	55·6
Emscher-lippe	213	2950	722	222	2200	559·1	1·39	22·3	77·6
Castellengo	177	875	175	111	850	107	1·53	24·5	61·5
Bernterode	79	1875	168	49	1875	104	1·51	24·2	62·0

* Paper read before the Rugby Engineering Society, March 10th, 1914.

ordinary values for acceleration, braking, velocity, torque, and horse-power for a steam winder. These have been developed from the set of continuous indicator diagrams, Fig. 3, taken from a two-cylinder engine running under normal conditions. The engine was very carefully driven for maximum economy, and was linked up after the first few strokes.

The steam accounted for on the indicator diagrams is always considerably less than that actually taken by the engines as measured by the feed-water consumption. In one carefully-executed test it was only about 50 per cent., 85·3lbs. of steam at 50lbs. per square inch gauge per indicated horse-power being evaporated, but only 45lbs. per indicated horse-power being calculated from the indicator

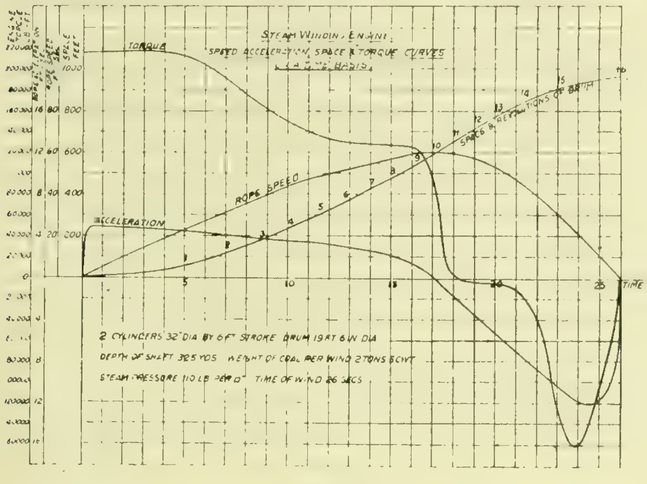


FIG. 2.

diagrams. The calculation of the feed input to a range of boilers specially set apart for a particular winder is a difficult matter in an ordinary colliery installation, and therefore reliable tests of steam winders are few. It is possible that the introduction of the steam-flow meter may provide a simple and convenient means of checking these consumptions, as such a meter can be installed in the engine steam branch and will give a continuous record of the steam used.

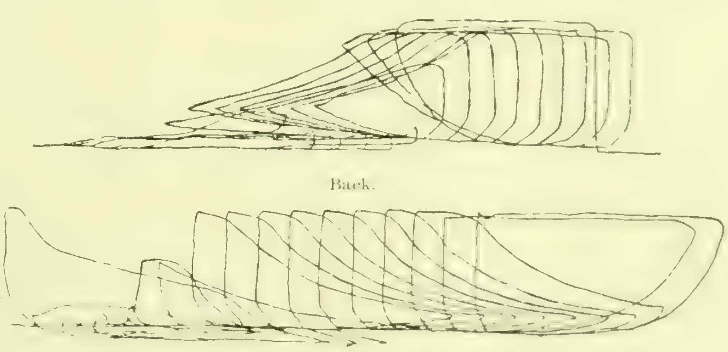
Table I. (taken from a recent article by Prof. Phillippi) gives the results of a series of tests taken on steam and electric winding engines. The steam winders were all of modern type and fitted with expansion gear. The "load factor" in the last column is the ratio of the effective horse-power during a test to the effective shaft horse-power of the installation, as given in column 3. In the table the Deutscher-Kaiser installation shows a particularly poor load factor. The winding depth was little more than half that for which the plant was designed, and during the test the weight of coal raised per hour only exceeded very slightly half of that provided for. It is also necessary to allow for the unfavourable influence of the mass and relatively great diameter of the winding pulley, and the relatively high weight of the cage. It is necessary to take into account other facts prejudicial to the electrical equipments tested. Flywheel converters of early design ran too slowly, and therefore required comparatively heavy flywheels; further, the efficiencies of the generators and three-phase motors were slightly inferior to those obtained at the present time in the case of flywheel converters of increased speed.

In the case of the steam-driven winding engines, it is necessary to draw attention to the difference existing between the consumption of steam measured during the tests and that for a whole day of 24 hours: for instance, a steam-driven winder at the Schurbank und Charlottenburg mine required 36·3lbs. of steam per shaft horse-power per hour during the winding period, but the consumption measured over 24 hours amounted to 58·1lbs. per shaft horse-power per hour. This shows that the figures sometimes quoted for steam-winding engines and obtained by tests extending over short periods only are of no value as a basis for an estimate of the true running charges. This remark also applies to rolling-mill engines. The results given compare very favourably with those obtained in this country in which the steam consumptions have been usually over 100lbs. per shaft horse-power. This shaft horse-power is calculated from the average useful weight of mineral raised per hour and the depth from which this is lifted.

It will be seen that from the point of view of energy consumption the electric equipments are superior to the steam. The electric motor, whether alternating or direct current, is particularly suited for winding duty; its starting torque may be as high as 2·5 to 3 times its normal full load torque, and in the case of the direct-current motor this starting torque is available at any point in a revolution. In alternating-current induction motors, owing to the effect of stator and rotor slots, there are slight variations of torque over a pole angle, but even at the point of minimum mutual induction between stator and rotor the maximum torque will reach the values given above, provided the machine is suitably designed. Thus the high starting and accelerating torques required are easily provided by an electric motor without the machine being of excessive size for the average load. Owing to the uniform nature of the starting torque that rate of acceleration can be chosen which gives the most economical relation between maximum and average torques for the wind. Electric winding engines are of two general types:—

(1) Those in which the control is effected by series resistance in the armature circuit in the case of direct-current machine, and in the rotor circuit in the case of alternating-current machines. This method is only economical when the starting and braking periods form a small percentage of the total time; it is used for small machines, or for larger machines where no variations of the maximum speed are required.

(2) Those in which control is effected by an external machine or machines; of this type the Ward-Leonard is the best. In this arrangement the armature of the winding motor is connected to a direct-current generator, the field strength of which may be varied from zero to maximum in either direction. The generator is driven by an engine, turbine, or electric motor at a more or less constant speed, and the voltage at the terminals of the winding motor armature will therefore vary with the generator field. The winder motor field is supplied from a separate source and is usually maintained constant; the speed of the motor will therefore vary approximately as the voltage supplied to its terminals. Thus any speed from zero to maximum in either direction may be obtained at will, and as the field current of a direct-current generator is only about 1 or 2 per cent. of its armature current, the apparatus for handling this current is correspondingly reduced. Further, if a braking



Back.

Front

FIG. 3.

effort is required on the winding motor, by reducing the voltage of the generator below the back electromotive force of the winder motor, a reverse current will flow, the motor becomes a generator and the generator a motor. The winder thus drives its motor as a generator and a braking effect of any desired magnitude is produced. This dynamic braking energy can be absorbed in various ways. If the driving motor of the motor generator set is an induction motor, the generator acting as a motor will tend to drive it above synchronism and thus return power to the line. Frequently a flywheel is coupled to the motor generator set to level out the peak loads. This flywheel will absorb the

braking energy, and store it ready for the next peak. The whole of the energy imparted to the moving masses, with the exception of slight losses in transformation, can thus be conserved with a resulting increase in the economy of the plant. In equipments of the first type controlled by series resistance it is not possible to conserve the braking energy. It is also not economical to run at any other speed than that for which the motor is designed, as doing so involves heavy losses in resistances, but equipments of this type have a definite field where their lower first cost balances their lower economy.

A diagram for a Ward-Leonard controlled winder is given in Fig. 4. This refers to a plant suitable for raising 267 tons per hour, or 2,000 tons per day from a depth of 730 yards. The weights of the various masses to be accelerated

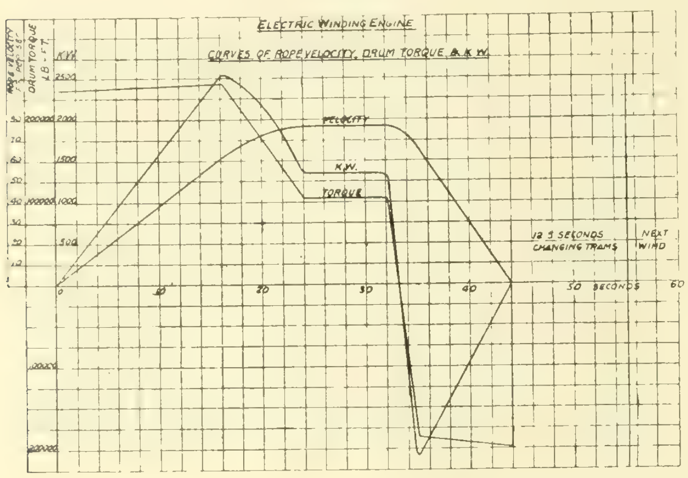


FIG. 4.
Weight of Coal per hour, 267 tons; weight of coal per wind, 4 tons; depth of shaft, 730 yards.

reduced to the rope amounted to 156,000lbs., including two direct-coupled motors, a drum 16ft. diam. by 13ft. 6in. wide, two cages each six tons, 16 tubs each 4 cwts., eight loads of coal each 10½ cwts., that is, 4 tons 4 cwts. per wind, the total weight of rope, including a balance rope, 21 tons. This machine will be supplied by a motor generator set running at 480 revs. per minute, driven by an induction motor of 1,400 h.p. with a 35-ton flywheel, 12ft. 6in. diam., coupled to the generator. The guaranteed consumption of power for this winder when raising 2,000 tons of coal per day was 17·8 Board of Trade units per wind, or 4·24 units per ton. This is equivalent to 1·71 units per shaft horse-power hour, or an efficiency from line to load of 43·4 per cent. This is a low value, but the conditions are against high efficiency owing to the small weight per wind and the very high speed (over 75ft. per second, or 51 miles per hour) required to raise the specified weight per hour. When raising 233 tons per hour, or 1,750 tons per day, the efficiency is slightly higher, 17·2 units per wind or 1·65 units per shaft horse-power, that is 45 per cent. overall efficiency. Two winders of this size will form the equipment of the colliery, the total output of which will be 4,000 tons per day. Assuming 250 working days per annum, this amounts to 1,000,000 tons per annum. A method of expressing the coal consumption of the colliery equipment as a percentage of the total output will in this instance give an interesting comparison. The other loads on this colliery plant would be as follows:—

Colliery Load.	Day.	Night.
Fan	275 kw.	275 kw.
Air Compressor	200 ,,	—
Screens	75 ,,	—
Creepers	10 ,,	—
Fitting Shops	20 ,,	10 ,,
Saw Mill	10 ,,	—
Pumping	—	150 ,,
Lighting	10 ,,	30 ,,
Auxiliaries Feed Pumps, Stokers Scrapers, Fans, &c.	175 ,,	100 ,,
	775 ,, Total	575 ,, Total.

The two winders will work for 9½ hours at full load, including 7½ hours winding coal and one hour, at the beginning and end of each shift, winding men; the average consumption for the two machines running together will be 2,203 kw. The total day load will therefore be 2,988 kw., say 3,000, and this will be taken by two 1,500 kw. turbines, the average steam consumption (at 15·6lbs. per kilowatt hour) being 46,000lbs. of steam per hour. Assuming a low evaporation of 6lbs. of water per pound of coal, the total coal used per day of 9½ hours will be 33·1 tons. Six Lancashire boilers, 30ft. × 8ft. 6in., each having a capacity of 8,000lbs. of water per hour, will be ample for supplying this load, as the chief demand, viz., that from the winding equipment, will, when the winders are working at full speed, be almost uniform, the peaks rarely exceeding the average by 10 per cent. For the working portion of the day alone, it will be seen that 33·1 tons of coal are required under the boilers. This is equivalent to ·88 of 1 per cent. of the total output of the colliery.

For the night load, we take the average of 575 kw. for 14½ hours; assuming a steam consumption of 20lbs. per kilowatt-hour, as this load is likely to be fairly uniform, the steam consumption per hour will be 11,500lbs. Probably this load will be taken by two boilers, the remainder being banked. Allowing for a low rate of evaporation, say, 4lbs. of water per pound of coal, the coal necessary for the night run of 14½ hours would be 18·63 tons. This allows for banking and relighting the other boilers, and also of a supply of steam for the necessary winds, which will be made during the night, for repairers, firemen, &c. This makes a total for night and day load of 51·73 tons, which is equivalent to 1·3 per cent. of the total output of the pit when working at full speed. Assuming that there will be 250 working days per annum, this leaves 115 idle days. For the idle days, which include Sundays and holidays, the load will be:—

Fan	Reduced speed	100 kw.	
Pumping	,,	50 ,,	
Lighting	,,	10 ,,	Day.
,,	,,	30 ,,	Night.
Auxiliaries	,,	50 ,,	
	Total	210 ,,	

The consumption per kilowatt-hour will be about 25lbs. at this low load, thus the average steam required per hour will be 5,250lbs. One boiler will be sufficient to carry this load, but it would be preferable to keep two boilers under steam to allow of occasional use of the winders at reduced speed. We therefore assume that two boilers are running during the idle days, evaporating 4lbs. of water per pound of coal. This will require 14·7 tons of coal per day of 24 hours. Allowing for banking of further four boilers, and relighting same 3·3 tons, this gives a total of 18 tons per day of 24 hours. For 115 such days the total consumption will be 2,070 tons. For 250 days, working at full output, the consumption will be 12,930 tons, making a total for 365 days of 15,000 tons of coal per annum, or 1·5 per cent. of the total output per annum. In a similar way, it may be shown that the coal consumption when running at slightly reduced output, say, 3,500 tons per day, or 875,000 tons per annum, would be 1·64 per cent. of the total output.

A steam winding equipment for the same output would require at least 60lbs. of steam per shaft horse-power hour, in view of the heavy starting torque, high velocity, and heavy braking losses. As the shaft horse-power is 663, the steam consumption per winder per hour would be 40,000lbs. To keep the piston speed down to a reasonable value the drum would require to be about 26ft. diam. In view of the fact that a balance rope is to be used, a cylindro-conical drum would not be necessary. If the engines were of the simple high-pressure type, two cylinders, 36in. diam. × 7ft. stroke, would be necessary. If of the tandem compound type, with automatic retaining valves on the receiver, the high-pressure cylinders might be smaller, and the consumption would probably be reduced by 20 to 25 per cent. The cost of this engine would be 30 to 35 per cent. higher than the simple engine, and the control gear and upkeep much increased. The exhaust steam from these engines would be available for use in turbines, and there would be obtained about 900 kw.

from each winder, allowing 32·7lbs. of steam per kilowatt-hour, a dryness fraction of 0·9 for the steam coming from the winders, and losses of about 5 to 7½ per cent. in an accumulator. In this instance only 788 kw. was required during the day, and a 500 kw. mixed-pressure turbine attached to each winding engine would give ample power. The average steam consumption for the two winders and all other loads would therefore be 80,000lbs. per hour during the winding period of 9½ hours, but the maximum demand would be very much in excess of this. One winder alone during the accelerating period would take steam at the rate of 100,000lbs. of steam per hour, and should the two start together the demand would correspondingly increase.

The boilers would therefore be working under very inferior conditions, and with the same coal as before the evaporation per pound would be about 5lbs. of water. To provide the necessary reservoir of steam for these peak loads at least 12 30ft. × 8ft. 6in. Lancashire boilers would be necessary. The coal consumption over the 9½ hours would be 67·8 tons. During the night it would be necessary to run one turbine and to permit of occasional use of one or other winding engine at least four boilers would be needed, the remainder being banked. The coal consumption for these boilers for 14½ hours at 10 cwts. per boiler per hour would be 29 tons. Thus the total for a working day and night would be 96·8 tons, that is 2·42 per cent. of the total output. For the 115 idle days steam must be available for the winding engines, and the average consumption of four boilers, with an allowance for banking or relighting the remainder, would be 36 tons per day of 24 hours, making a total of 28,340 tons per annum or 2·834 per cent. of the total output.

It appears that the electric winding equipment is preferable from the point of view of economy, and there can be no doubt that it is superior to the steam winder in ease of operation, accuracy of control, and owing to its uniform torque less severe on ropes, headgear, and moving parts, it is certainly equal, if not superior, in reliability. It is, however, in nearly all cases higher in first cost, and its higher economy has to be carefully considered against this factor. Taking the above example, the capital cost of the two electric winders, including drums, gear, motor generator set with two 35-ton flywheels, three 1,500 kw. turbines with condensing plant, eight boilers, buildings, foundations, and all the necessary accessories, is £80,000. For the complete steam winding equipment, with two 1,000 kw. mixed-pressure turbines, boilers, buildings, &c., the total cost would be £60,000, or 25 per cent. less than the electric winder and high-pressure turbine equipment. As a further comparison, a scheme including electric winders and a set of four 1,000 kw. gas engines and generators, gas producers, and by-product recovery plant, including a spare producer set, would cost £158,000. The following running costs include interest and depreciation, repairs, renewals, oil and waste, enginemen and stokers' wages, &c. Depreciation varies with the different portions of the plant from 3 to 7½ per cent. Interest on capital is taken at 5 per cent.

	Running cost per annum. £
For the electric winding and horse-power turbine plant	19,800
For the steam winding and mixed-pressure turbine plant	23,600
For the gas engine and electric winding plant...	25,600

These costs are based on an output of 1,000,000 tons per annum, and the gas engine plant is credited with the value of the by-products. The steam winding plant might be placed on a slightly more favourable basis if a market were available for the surplus power which would be generated from the exhaust steam. In the case of a group of collieries, this power could probably be disposed of. Assuming that 1,000 kw. surplus can be produced during the winding period, this equals 2,375,000 units per annum, which would have a value of about 0·15d. a unit, or £1,500 per annum. This would be credited to the steam equipment, reducing the running charges to £22,100 per annum, or 11·5 per cent greater than the electric winding equipment

(To be continued.)

HARPER'S FRICTION CLUTCH.

THE clutch shown in the accompanying cuts has been recently patented by Messrs. Harpers, Ltd., Craiginches Iron Works, Aberdeen, and Mr. Thomas Mowat, M.I.M.E. It is of the internal expanding type, in which shoes are moved radially outwards into engagement with a drum by a rocking arm, and has been designed to render such clutches readily adjustable. In order to effect this, right and left handed screw-threaded rods operated by a nut on a rocking arm, engage with eccentric pins carried by the clutch shoes. Referring to the illustrations, L is the clutch drum loose upon the shaft and M the shoes which can be thrust radially outwards into engagement

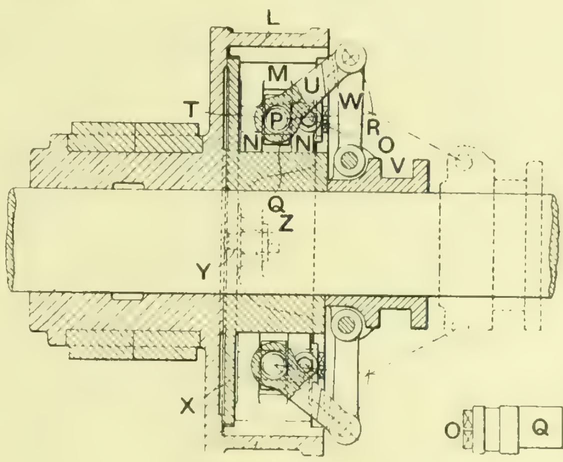


FIG. 1.

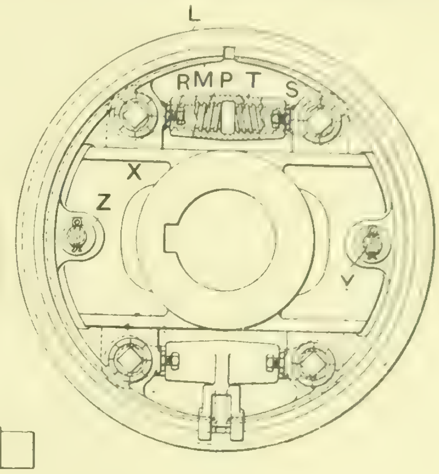


FIG. 2.

HARPER'S FRICTION CLUTCH.

with it. The shoes are provided with lugs N carrying the pins O. Right and left-handed screw-threaded eye bolts P are provided in which the eyes engage with the eccentric surface Q of the pins. R are locking bolts and S locking nuts to prevent the pins O from turning. Right and left-handed screw-threaded nuts T engage with the eye bolts P. U are arms on the nuts T, which are linked to the sliding collar V by the links W. The lugs N are guided by the plate X keyed to the shaft. The plate X has also guiding pins Y passing loosely through lugs Z on the shoes M. In the illustrations the clutch is shown in engagement. If the sliding collar be withdrawn to the dotted position shown in Fig. 2 the nuts T will be turned by the links W and arms U and the shoes M drawn out of engagement with the drum. In order to adjust the clutch one or more of the lock nuts S and bolts R are slackened, and one or more of the pins O are then turned the required amount and again locked in position by the bolts R and nuts S.

Death of Mr. George Westinghouse.—We regret to announce the death of Mr. George Westinghouse. Born at Central Bridge, Schoharie County, New York, 68 years ago, he early displayed remarkable mechanical aptitude, and at the age of 15, while working in his father's machine shop, invented a rotary machine. He served as an assistant engineer in the United States Navy during 1864-65. In the latter year he brought out a device for replacing railroad cars on the track, and three years later produced his great achievement, the air brake. Other inventions he introduced had relation to steam and gas engines and steam turbines. He was the pioneer in introducing alternating-current machinery in America, which has rendered possible the great development of water power for long distances. He built the great generators at Niagara Falls, and those for the Elevated Railway and Rapid Transit System in New York. He was president of numerous corporations, employing over 20,000 people.

PNEUMATIC TOOLS.*

BY H. I. BRACKENBURY.

(*Concluded from page 254.*)

THE problems presented to the manufacturer of pneumatic tools differ considerably from those involved in the production of other machines actuated by a fluid under pressure. The desirable qualities in a pneumatic tool in their order of importance appear to be: Reliability, power, cheapness, lightness, ease of handling, and compactness, and low air consumption.

Up to the present probably too little importance has been attached to the last of these desiderata. It is no uncommon thing to find a large and expensive air compressor plant eating up power and delivering enormous volumes of air to supply the incessant drain of leaking pipes and hoses, and the intermittent demands of most wasteful types of tools. This fault is largely due to the infrequency with which the supply of air is measured. There are now on the market several types of instruments which will indicate the rate of flow of air with reasonable accuracy, though the price asked for them, at present, is rather high, owing, no doubt, to the small demand. Perhaps it would be no exaggeration to say that quite generally the amount of air lost by leaking hoses is almost equal to that used by the pneumatic tools themselves. The leak can be easily found by testing at meal hours, when the pneumatic tools employed will not be in operation, but the leak will be unaffected if the compression plant be kept running. Without doubt the convenience and reliability of these tools fully justify their employment even under present conditions, but the following considerations may induce those that employ them to exercise greater vigilance in avoiding waste.

Suppose that there are a number of leaks equivalent to a circular hole of about $\frac{1}{10}$in. diam., a case that would be only too easy to discover. If the air supply be at 100lbs. per square inch pressure, the air leak will be about 15 cub. ft. of free air per minute, or about 2 cub. ft. per minute of the compressed air. The power required to compress this will be nearly 3 h.p., so that the cost of the leak will probably be about 2d. per hour. In other words, the leak would waste about 120 cub. ft. of compressed air per hour, costing about 1s. 4d. per thousand cubic feet—nearly as much as what is paid for coal gas.

The factors governing the design of pneumatic drilling machines are entirely different from those for fixed machines. In the latter case, the machine is designed to run the drill at the speeds and feeds which will give the quickest penetration without undue wear to the drill. In the case of the pneumatic drill, the power is the governing factor, and therefore the design must be such as to use that power to the greatest advantage, *i.e.*, to rotate the drill at the speed at which the greatest penetration is given for the power. This speed is a slow speed, and not a high speed. The author found, without going to any extreme limits, that an ordinary drilling machine required, for the same rate of penetration with fast speed and fine feed, double the power required with slow speed and coarse feed. These experiments were made with a drill in careful alignment with the work, and not, as may often be the case, with a pneumatic drilling machine supported by a springing arm and starting with the drill at anything but right angles to the surface of the work, conditions which would tend to increase the drill friction. The result is that the best effects are obtained by running the drill at slow speeds, and not at high speeds. The limit in this respect would be reached if the pressure required to feed the drill were more than could be conveniently given by the feed gear, or the torque exceeded the strength of the drill body or cutting edge.

TABLE I.—*Drop of Pressure in Armoured Flexible Hose, 16½ft. Long, ½in. Diameter Bore.*

Initial Pressure, 85lbs. per square inch.

Flow. Cubic feet per minute of free air.	Drop. Pounds per square inch.
5	1·5
10	2·0
15	3·0
20	3·3
25	4·0
30	5·5
35	7·5
40	8·5
45	10·0
50	12·0
55	14·0
60	16·8
65	18·5
70	20·0

Drop in pressure has a very important bearing on the design of tool which may be employed to advantage. Let us take as an example the tests of a pneumatic drilling machine connected to the main supply by a length of 16½ft. of hose of ½in. internal diameter. As shown by Table I., if the drill uses 70ft. of free air per minute and the pressure of air on entering the hose is 85lbs., the pressure at the drill will only be 65lbs. When the air is allowed to flow into the drilling machine, a high speed of rotation is set up until the feed is applied by the feed screw. The more rapidly the feed screw is rotated the quicker will be the penetration of the drill and the slower will the drill rotate, with the final limitation that if the feed is too rapid, the drill will stall suddenly and there will be no penetration. This appears to be a curious paradox, for, apart from considerations of wire drawing, the indicated horse-power of the pneumatic engine would seem to be dependent on its speed and the pressure of the air. But since the flow of air is decreased at the slower speed, the pressure rises and the torque increases. The result arrived at therefore is that the maximum speed of penetration is given by that speed of rotation at which the machine develops its minimum horse-power, but its maximum stable torque. Considerable experience of running drills under test conditions has proved the importance of applying the feed with judgment. A man used to this work can get much better results out of a drill than can another man, equally intelligent and skilful, who is not so accustomed. It requires the greatest judgment in order to feed the drill so rapidly that it shall just—and only just—escape stalling. It has been found that the feed must be reduced slightly just before the drill breaks through the metal.

Perhaps at this point it may be well to mention that the above considerations apply only to those cases where the power given out by the pneumatic tool is less than that which can be used by the twist drill without requiring to be ground too frequently. With modern high-speed twist drills of ½in. diam. and above this is practically always the case. The idea of a minimum speed at which the pneumatic drill will run without stalling is of importance, because it should help to fix the gear ratio to be employed between the pneumatic motor and the twist drill. As already shown, this critical speed is probably dependent not only on the size of the twist drill and the material it is to cut, but also upon the laws connecting the torque of the pneumatic motor with its speed of revolution, while this relation in its turn depends upon the pressure of air supply and the length and bore of the flexible hose. However, let us consider for the moment that the critical speed is a constant and is known. Let us suppose that it is 200 revs. per minute. Then, if the relation of the horse-power of the pneumatic motor to its speed of revolution is known, the gear ratio may be designed so that the motor shall give out the maximum horse-power when the twist drill is running at 200 revs. per minute.

The history of other prime movers would indicate the probability that there will be, and should be, an increase in the speed of revolutions of the pneumatic motors on drills. The advantages obtainable by such change are almost self-evident. Everything is to be gained by obtaining increased power from the same piston by running it faster, provided the design still ensures reliability and good wearing qualities. However, if this change occur, it will necessarily involve an increase in the gear ratio between the drill and pneumatic motor.

Perhaps it may be allowable here to point out a contrast between the humble "Windy Drill" and its more lordly cousin, the motor-car engine. In both cases the desire has been to get a larger output of power from a given size of engine. But while the motor-car engine has been set to drive its attached machine at ever-increasing speeds, the unfor-

* Abstract of paper read before the Coventry Engineering Society, Coventry, January 23rd, 1914.

tunate pneumatic engine is doomed to rotate its twist drill at the minimum stable speed, as long as the man in charge takes the trouble to work it at its full capacity. If the bore and stroke of the engine be fixed, the gear ratio should therefore be higher or lower according as the maximum power is developed at a high or low speed. It may be said that all pneumatic drills which are operated by pistons and crank shafts at present run at very low piston speeds, indeed, lower than most slow-speed steam engines. As in the case with the petrol engine, the difficulty is to get adequate valve area.

We have already seen how important is the effect of skill in feeding a pneumatic drill in order to make it give the best results. Let us trust that the future has not in store for us both professional racing drillers and specially designed racing drills. However, if such be the case, we must picture to ourselves a machine with enormous valves and an abnormal gear ratio, so as to enable the pneumatic motor to run at an excessive rate while the twist drill, fed downwards by a powerful feed motion, rotates at the lowest possible speed at which its motion is stable.

Pneumatic drills may be divided into two classes. The first class comprises those operated by an engine of the piston and crank shaft type, the second those which rely upon some form of rotary engine. The second type is attractive on account of its beautiful simplicity, but, so far, the author has not found one capable of giving as large a torque for a given air consumption as those of the first type. The principal difficulty in producing even a reasonably efficient rotary pneumatic engine is the large leakage, which seems almost inevitable.

In considering the efficiency to be expected from either type, we should remember that the problems to be faced by the manufacturer of an engine as minute as that required for a pneumatic drill are peculiar to the production of any very small device operated by a fluid under pressure. Since the periphery of a body is proportional to its linear dimensions, while its area varies as their square, it follows that the leakage which occurs at a periphery assumes greater and greater relative importance as the size of the part decreases.

Thus, suppose we have two pistons, one 1in. diam. and the other 2in. diam., each working (without piston rings) in a cylinder 0·001in. larger in diameter. Their areas are respectively 0·785 sq. in. and 3·141 sq. in., while the areas of the clearances are 0·003 sq. in. and 0·006 sq. in., *i.e.*, the clearance of the smaller area is 0·382 per cent. of its area, while that of the larger is only 0·191 per cent. of its area. Further, if the pistons are similar in shape, their lengths will be proportional to their diameter, and any air escaping round the larger piston will have to travel twice the distance that is traversed by the leak round the smaller one. Consequently the waste of air will bear a much greater proportion to that usefully employed in the case of the smaller piston as compared with the larger—in fact, the ratio will be probably more than four times as great. We see, then, that as far as leakage is concerned, we must not expect as good results from a small engine as from a large one, and, in fact, it is found that leakage is the principal bugbear of the designer of pneumatic tools.

Compressed air, as is well known, contains, or may contain, available energy in three forms, viz., kinetic energy due to the velocity of its flow; internal energy, which it can give up on expansion; and the energy due to its pressure and volume, which it can transmit to a piston without expanding. The third type of energy is comparable with that transmitted by the water in an hydraulic pressure main. In most tools as designed at present, this third form of energy is the principal source of power. The purchaser has demanded the maximum possible torque, combined with a minimum size and weight, to gain which all considerations of ideal efficiency have been sacrificed. This has prevented the employment to any large extent of the expansive energy of the working fluid. However, it is possible that another difficulty, now to be considered, has hindered the development of a more efficient thermodynamic cycle.

The exhaust outlet of a drill, working during cold weather, is frequently coated with hoar-frost, and cases are not very rare of some types of drills actually freezing up. In testing a drill in Russia, it was found that the exhaust playing on the inlet pipes had cooled it to such an extent that the pipe was blocked by a cylinder of ice, the moisture in the incoming air having, evidently, been condensed and frozen. This is not due, as is often thought, to the lowering of the temperature of the air during adiabatic expansion in the cylinder. The expansion ratio is never sufficient to produce such an effect; in fact, there is seldom any expansion at all. The cause of the trouble is that the air escaping through the exhaust port expands rapidly and gathers velocity up to an enormous figure. Now the kinetic energy, which the air then possesses, due to its high speed, is produced at the expense of the internal energy, which it previously contained when under pressure. Consequently, when the exhaust air is rushing along its way to the atmosphere its internal energy must be much less than when it was in the cylinder. It follows that its temperature must drop. This, of course, is perfectly well known to the most elementary student of thermodynamics, but it may be worth while to follow the application of the theory to this particular case. If the exhaust air could be brought to rest by causing its kinetic energy to be degraded into heat by means of friction, then its temperature would again rise until it was very nearly equal to what it had been in the cylinder of the drill (the slight difference is, of course, known as the Joule Thomson effect). The difficulty would probably be to bring this about without producing a back pressure on the piston.

The exhaust of the pneumatic drill may cause the designer other difficulties besides freezing up. Many drills work with practically no expansion. It follows that the moment the exhaust port is uncovered the cylinder must clear itself as quickly as possible of its contents. But the air in escaping expands, so that, in order to avoid all back pressure on the return stroke, the area of the exhaust port would have to be enormous.

If we remember that during the working stroke of a petrol engine the gases are expanding and losing heat to the walls of the cylinder, and yet the exhaust valve has to be designed with a quick lift, and a diameter about one-third of that of the cylinder, we shall realise the difficulties in the case of the pneumatic drill. Unfortunately, the minute size of the latter—apart from other difficulties—renders it almost hopeless to try to take indicator diagrams, so that we cannot be sure exactly as to what goes on in the cylinder. However, it seems highly probable that in most types the back pressure increases very rapidly with increase of speed of running. It should be worth while to try to make a drill with much larger exhaust valves than are at present used, provided with a high gear ratio, so that the engine, which would be smaller than usual, would run at a higher speed without increasing the speed of the drill. Possibly this would lead to smaller proportional leakage losses, since in a given design these should be nearly constant, while the useful air consumption should be approximately proportional to the speed.

Some of the difficulties inherent to the design of pneumatic tools have already been considered, but no reference has been made to the possible thermodynamic efficiency of these machines. This depends, of course, upon the cycle adopted for their operation. Now it must be distinctly understood that, however much importance we may attach to efficiency in the case of these particular machines, the primary consideration is the attainment of large power for small weight and size. We are therefore prohibited from employing a high expansion ratio, if, indeed, it be worth while to expand the air at all. Further, the rapid lowering of the temperature of the air on expansion would limit this ratio, apart from other considerations.

Obviously the possible thermodynamic efficiency is largely decreased by this limitation. Moreover, the proportion of the total energy contained in the air which is available for useful work decreases with increase in the air pressure. The whole of the theory of this subject is perfectly well known already, and can be found in any standard book, such as Cotterill's "Applied Mechanics," but the following expression is in a form which may be of interest to us in connection with the present subject. If we assume that a pneumatic motor is supplied with dry air at P_1 atmospheres pressure, and that it works without expansion, then it may be shown that the fraction of the available energy in the air which it uses is given by the expression

$$\frac{2}{7} \cdot \frac{P_1 - 1}{(P_1^{\frac{2}{7}} - 1)\, P_1^{\frac{5}{7}}}$$

The following table has been calculated from this formula.

Further, it may be shown that if cut-off takes place at one-ninth of the stroke, then the fraction of the available energy in the air which is used is given by the expression

$$\frac{P_1\left\{1{\cdot}4 - \left(\frac{1}{Q}\right)^{0{\cdot}4}\right\} - 0{\cdot}4\, Q}{1{\cdot}4\, P_1^{\frac{5}{7}}\ (P_1^{\frac{2}{7}} - 1)}$$

Absolute Pressure of Air in Atmospheres.	Percentage of Energy Available.	
	No Expansion.	Cut-off Half-stroke.
1·25	—	—
1·5	87·5	69·5
2·0	79·0	94·5
2·64	—	100·0
3·0	70·5	98·0
4·0	65·5	96·5
5·0	62·0	92·0
6·0	59·0	89·5
7·0	57·5	88·0
8·0	56·0	86·0

The author believes that this little point in the thermodynamics of the pneumatic motor has not been clearly indicated previously.

The measurement of the brake horse-power of a pneumatic drill offers no particular difficulty if great accuracy be not required. For commercial purposes a prony brake is quite satisfactory. If, however, it be desired to investigate comparatively small changes of brake horse-power, a number of difficulties have to be surmounted. Two forms of brake have been tried. The first consisted of a hollow copper jacket resting on a sheave, which was driven by the drill. The axle of the sheave on one side ran in a single "Skefko" ball bearing, while the other end was turned to a Morse taper to fit into the drill chuck. The back centre of the drill abutted on a support carried on an old lathe shifting head. The whole arrangement was fitted to a discarded lathe bed. Arrangements were made to keep a stream of cold water flowing continuously through the copper jacket. The latter was lined with lead, so as to bear evenly on the sheave. To one end of this copper jacket there was attached a heavy weight resting on a spring balance, while a lighter weight attached to the other end was immersed in a vessel of oil, which damped down the oscillations until they did not exceed about ¼lb. on the spring balance. Of course the lighter weight was corrected for the up-thrust of the oil.

This arrangement was only fairly satisfactory. It was adopted originally in an endeavour to keep the coefficient of friction constant. However, in spite of the water cooling of the brake, the temperature of the sheave rose slightly, and the load varied a little during a run. Greater difficulty was caused by the wear of the brake.

The brake used with it consists of a fine-quality cotton webbing, and the sheave has been made of larger diameter so as to minimise the rise of temperature. Both with this and the former brake elaborate precautions must be taken to prevent oil or water reaching the surface of the sheave—even contact with the hand altering the coefficient of friction. It is intended to substitute ball bearings for the present plain bearings, and to make better arrangements for taking up the stretch of the belt. Probably, also, it will be necessary to introduce some spring control on the brake, though the running is much more stable than might be expected.

The most surprising thing about testing drills is the accuracy attainable in the penetration test. If the same man always be employed in feeding the drill through the plate, and precautions be taken to keep all other factors constant, the time of drilling can certainly be found to within two or three seconds per minute. This has been repeatedly proved by submitting drills for test with secretly-altered reference numbers. An accuracy of 5 per cent. is quite as much as can be expected in most commercial testings of brake horse-power, since this involves reading the revolutions per minute and the net load on the brake, each correctly to within 2½ per cent. In consequence of this most tachometers are not sufficiently accurate for exact work, and the speeds should always be obtained by means of a revolution counter.

The practical testing of pneumatic drills is difficult, but the testing of pneumatic hammers for power is even more so. The apparatus used in testing pneumatic hammers consists of a massive cast-iron bed provided with T-grooves, so that a heavy block may be bolted to it in any desired position. Against this block is placed the handle of the hammer to be tested, resting in a formed recess lined with leather, to prevent marking the polished surface of the handle. The snap of the hammer abuts against a heavy block, which can swing about a vertical pivot fixed to the bed. This swinging block is controlled by a spring, which can be adjusted by means of a screwed bolt passing through the fixed abutment. To the swinging block is fixed a light-steel arm carrying a stumpy pencil, the point of which rests on a strip of paper which can be reeled by hand off one drum on to another. As the instrument is only required to give the speed of the hammer, and a general idea of the type of oscillation produced, there is no need to employ a uniform drive for winding the paper. The hammer can be reversed in its support, so as to show the vibrations of the handle.

The work required to be done by the light pistons used in some of the best-known chipping hammers requires material capable of withstanding vibration and shock to an exceptional degree. An an example, a piston weighing 8 ozs. now does considerably more work than a piston weighing 14 ozs. of an older design. It will therefore be apparent that where no difficulty exists in finding suitable material for the latter, much care must be exercised for the material selected for the former. Each piston should be tested by the Brinnell ball test; but before selecting any new form of material, further tests are required. An ordinary test for the smaller pistons is 60,000 blows from a heavy riveting hammer; for a special test 500,000 blows or more are used. The piston must show no signs of setting up or fracture.

Finally, although the production of a perfect pneumatic hammer appears to be more difficult than the production of a perfect pneumatic drilling machine, the author believes that the designs of hammers have reached a point nearer finality than the designs of drilling machines. From the preceding observations on the points of efficiencies in the drilling machines it will be gathered that there is still room for considerable improvements in this direction. There can, however, be no doubt that the reliability of these machines has been immensely improved within the last few years, as the material for each part is now chosen with the most careful analyses of the duties it has to perform, and nothing is left to chance.

IMPROVEMENTS IN CENTRIFUGAL PUMPS.

THE accompanying illustrations show a design of centrifugal pump of the type comprising a rotor chamber having an outer converging portion terminating in a narrow opening and a rotor having converging blades adapted to rotate within the converging portion of the rotor chamber, the invention of Mr. J. Johnston, and the Globe Pneumatic Engineering Company, Ltd., 1, Victoria Street, Westminster, London, S.W. Figs. 1 and 2 are respectively a transverse sectional elevation and a side elevation, and Fig. 3 is a side elevation of the rotor shown in Fig. 1.

The pump casing A is formed in two parts and so constructed and arranged as to provide for two annular feed chambers B disposed symmetrically with respect to the centre line of the pump and a wheel chamber C intermediate of the annular feed chambers, and within which the pump wheel or rotor D is adapted to rotate. The rotor D is formed with a substantially triangular portion E terminating in a comparatively sharp edge at the outer periphery and is provided with blades F also adapted to converge towards the outer edge. The wheel D is slotted at convenient intervals around its periphery and the triangular-shaped blades F are forced tightly into and secured within such slots, the projecting edges of the blades being dished or spoon-shaped. The wheel chamber C is formed such that the blades work in a comparatively narrow passage between the converging portion E of the rotor and a corresponding converging portion G of the wheel chamber. The annular feed chambers B communicate with the wheel chamber by inclined ports H entering the wheel chamber in such a manner that the wheel blades F project beyond the ports at each side and the liquid to be pumped enters the feed chambers by means of one or more tangentially arranged inlet pipes J passing thence through the inclined ports H on to the wheel blades.

When the liquid enters the wheel chamber it passes outwardly along the blades F and thereby acquires an acceleration before being thrown off through a narrow neck K formed round the outer periphery of the wheel chamber and passing through which the liquid enters more or less tangentially a diverging annular chamber L surrounding the wheel chamber. The blades F are arranged upon the rotor in such a manner that they are tangential to a circle, the radius of which is approximately one-half that of the rotor. By reason of their tangential arrangement and scoop shape the liquid, it is claimed, enters the blade without shock and

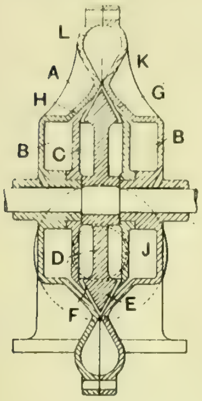


FIG. 1.

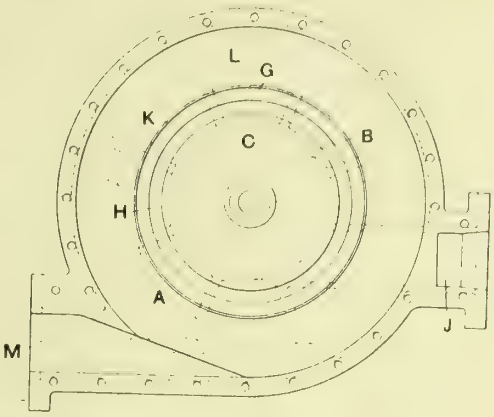


FIG. 2.

IMPROVEMENTS IN CENTRIFUGAL PUMPS.

is accelerated without changing its direction. This acceleration is continued outwardly for the whole length of the blade to the point where the two streams converge together and the liquid is projected at the moment of greatest velocity through the narrow neck K into the diverging chamber into which it enters in a more or less tangential direction (according to the volume passing) and around which it circulates, passing out through the discharge opening M which is made diverging as shown so that the velocity energy is transformed into pressure energy, the liquid leaving the annular chamber in a tangential direction. The blades F project inwardly beyond the ports H leading from the annular feed chambers B, and this arrangement ensures that any liquid passing from the port H inwardly towards the centre of the machine acts by centrifugal force to check the further inflow so that the central portion of the wheel does not become flooded, but always revolves in vacuo so that fluid friction is reduced to a minimum. The converging portion G of the wheel chamber and of the blades is made of a length approximating to one-third the total radius of the wheel chamber. This proportion, however, may be varied to suit varying conditions. The effect of increasing back pressure upon the pump is to cause the particles of liquid passing through the narrow throat K to issue in a direction which becomes more and more purely tangential so that the effective discharge is decreased but the circulating velocity in the outer annular chamber is increased, thus counteracting the effect of back pressure and forming a simple self-regulating device.

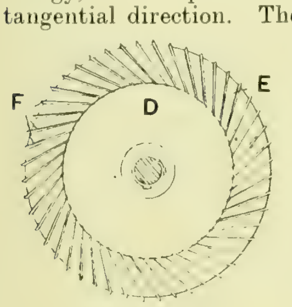


FIG. 3.

International Engineering Congress, 1915.—Rapid progress is being made in working out the final programme of papers for the International Engineering Congress to be held in San Francisco in 1915. The first volume of the publication of the Congress will consist of a series of articles descriptive of the various technical features of the design and construction of the Panama Canal. The various topics will be treated by someone on the canal force who has been responsible for the design and construction described. This volume will constitute practically an official technical record of the gigantic engineering feat which is just nearing completion. The programme of papers for the various sections of the Congress is practically completed. Subscriptions to the Congress are being received daily and on March 1st the number of enrollments was slightly in excess of 1,200.

MOTOR AND CONTROL EQUIPMENTS FOR ELECTRIC LOCOMOTIVES.*

BY F. LYDALL.

(*Concluded from page 252.*)

So far the question has been discussed only in relation to continuous-current motors controlled in the well known way by means of inserted resistances cut out in successive steps. To a certain extent the same problem is met with when alternating-current motors are employed either with rheostatic control or with voltage control obtained by drawing current from successive tappings of a transformer. The actual variation of motor torque from step to step will, however, depend upon a factor which is absent in continuous-current working, viz., the effect of the self-induction of the motor windings on the motor characteristics. This effect, so far as the speed-current curve is concerned, is similar to that of a large increase in the internal resistance of the motor, and therefore greatly reduces the fluctuation of the torque for any given number of steps. As an example of this effect, the speed curves in Fig. 7 may be compared with those in Fig. 4. The difference in the number of steps for the same fluctuation of torque in the two cases is obvious.

Going back to the general question, it is evident that the irregularity of the effort exerted by the motor equipment of an electric locomotive is a disadvantage which under certain circumstances reduces the usefulness of the locomotive. The question may be raised as to whether this disadvantage in the electric locomotive cannot be overcome by means which are commercially practicable. For continuous-current equipments variable voltage must be obtained by some form of motor-generator, the motor taking current from the power supply, and the generator delivering current at a suitable voltage to the driving motors, the voltage being varied as required by the excitation of the generator. This method is open to the great objection that the motor-generator is practically a substation installed in the locomotive, and is extremely bulky and expensive, and costly to maintain.

The case is quite different, however, with large locomotives equipped on a single-phase alternating-current system. Voltage variation can be very conveniently provided without using rotating machinery in the case of alternating current. Definite steps of voltage can be obtained simply by providing taps on the secondary winding of the step-down transformer, and there are various well-known methods at present in use whereby the maximum number of voltage steps is obtained with the minimum number of contactors. In spite of the advantages of these different schemes, however, it is not practicable to go very far in the direction of fine graduation. In practice, owing to the requirements of single-phase motor design, the voltage even at full speed is seldom more than about 300. It is also customary to employ large motors for these locomotives, and consequently the motor current which must be dealt with by the controlling contactors may be very heavy.

The alternative is to use an induction regulator or variable transformer in which the primary winding is mounted on a movable core arranged so that it can be turned round into any position relative to the fixed secondary winding, the mutual inductance and therefore the ratio of transformation being varied as gradually as desired from zero to a positive or negative maximum. This method has the great advantage of simplicity, as it entirely eliminates the contactors and the tappings on the low-tension side of the main transformer. It has, however, also the serious disadvantage of introducing into the locomotive a bulky and heavy additional piece of apparatus which adversely affects the efficiency and the power factor of the equipment.

An alternative method, which is in reality a combination of the contactor system and the induction-regulator system, was worked out by the present writer about eight years ago, and has been adopted on several of the single-phase locomotives equipped by Messrs. Siemens Schuckert for the Prussian State Railways. This method consists in the employment of a small induction regulator combined with a number of contactors which control the connections from the

* Abstract of paper read before the Institution of Electrical Engineers.

motors to the tappings of the low-tension winding of the main transformer. The function of the regulator is to increase the voltage at the terminals of the main motor or motors as gradually as may be required until the voltage corresponding to the next higher tapping of the transformer is reached. At this point a change is made in the circuit connections by closing a fresh contactor and opening the one previously closed, which operation can be effected without giving rise to any local short-circuits or serious sparking or difficulties of any kind. If the number of contactors employed is, for example, four, the capacity of the regulator is reduced to one-quarter; if six, it is reduced to one-sixth. Whatever the number and the consequent reduction in size, however, it is possible and easy to ensure that the voltage variation shall be as gradual as may be desired.

There are various ways of carrying out this method, but probably the simplest is shown, quite diagrammatically, in Fig. 8. In this diagram six tappings and six contactors are shown. The voltage of the secondary winding of the regulator through which the main current flows is exactly equal to the voltage between any two adjacent tappings. Current passes into the secondary winding at either end according to which end is connected to a closed contactor and passes out from the middle point to the motors. The tappings are connected through the contactors alternately to two leads x and y; 1, 3, and 5 being connected to x, and 2, 4, and 6 to y. The ends of the regulator secondary are permanently connected to these leads x and y. For the minimum voltage, contactor 1 is closed, the primary of the regulator being in

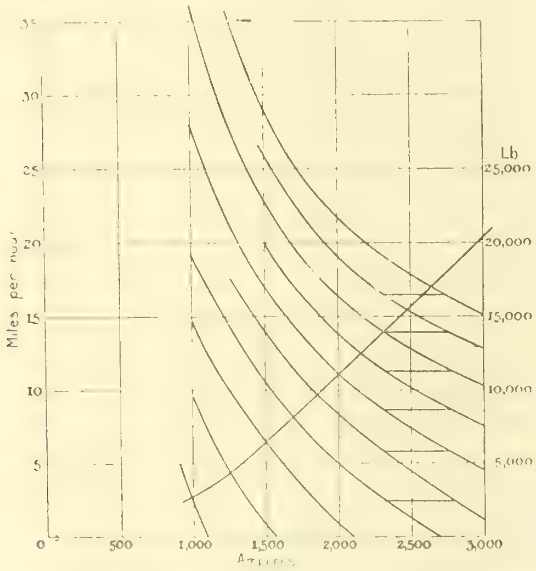


Fig. 7.—Speed Curves of 700 H.P. Single-Phase Railway Motor.

such a position that the voltage induced in the secondary opposes the voltage of the main transformer. To increase the voltage, the regulator is turned round until the voltage induced in its secondary is added to the voltage of the main transformer. At this point contactor 2 is closed, and contactor 1 opened, and the circuit is in this way re-arranged so that the regulator voltage opposes the main transformer voltage corresponding to the second tapping. The regulator is then turned round again as before and the process repeated until the full voltage is reached.

Referring once more to continuous-current locomotives, the importance of avoiding shocks also has its influence on the control equipment. During the starting period there are at least two occasions when shocks of greater or lesser severity are possible and are to be avoided, so far as may be, in the interest of the couplings between wagons. The first occasion is when the current is first switched on to the driving motors. If all the couplings were taut it would not matter very much if the full starting effort of the motors were exerted immediately. But if, as is very frequently the case with goods and mineral trains, the couplings are slack, it is strongly advisable that the initial pull of the locomotive should be only sufficient to take up the slack in the couplings before the train is accelerated. In this connection it must be observed that trains may be made up with the full number of wagons or with very few, and in both cases care must be taken to avoid a shock. The control equipment must therefore be arranged so that the tractive effort on the first notch or step of the controller is relatively quite small.

It should also be remembered that if the starting acceleration of the locomotive when working light is too great, it may be difficult for the locomotive driver and his mate to keep their feet. For example, suppose a 64-ton locomotive is designed to exert an average tractive effort during the start of 23,000lbs., the acceleration which this effort would produce with the locomotive alone would be something over three miles per hour per second. It would be almost impossible for a man to stand up against this acceleration if it were applied suddenly. It would therefore be necessary to install sufficient resistance in the locomotive to reduce the tractive effort on the first step to something like 5,000lbs., which would produce an initial acceleration of about 0·6 mile per hour per second. The other occasion on which the shock is to be avoided is during the transition in the grouping of the motors from series to parallel. This can be effected by employing the well-known bridge system of control, in which the full torque is maintained by the driving motors right through the transition stage, subject of course to the fluctuations that occur to the same extent during the whole of the starting period. Provided only two motors or two groups of motors are used in a single equipment, the two being connected successively in series and in parallel, there is no difficulty at all in arranging the control equipment on the bridge system. It is otherwise, however, when there are four motors to be arranged in three groupings, viz., series, series-parallel, and parallel. It is a simple matter to arrange one of the transitions on the bridge method, but for the other it is hardly practicable, though theoretically quite possible, to pass through the transition without a momentary reduction of the tractive effort to quite a low value.

Dealing now with the arrangement of the controlling resistances, it is to be observed that with the same number of steps the fluctuations of torque are much greater in the series than in the parallel grouping. To put it in another way, in order to keep the fluctuations within given limits as mentioned in the beginning of this paper, it is necessary to provide more steps for cutting out resistance in the series grouping than in the parallel. This can be done most conveniently, and without involving the provision of any more contactors, by arranging the equipment on the bridge system, in which each motor or group of motors has its own set of resistances and contactors for cutting out these resistances in steps, and by cutting out one section of resistance from each of the two sets alternately while operating in series and cutting out the same sections simultaneously when operating in parallel.

The material most generally used for the main controlling resistances in continuous-current locomotives is cast iron. This can be either plain grey cast iron, or an alloy which contains certain ingredients giving qualities of elasticity and high resistance. For small currents one of the alloys is generally employed, but for large currents simple cast iron may be used, providing care is taken in selecting thoroughly sound castings. There is no difficulty in obtaining grids having a specific resistance of about 80×10^{-6} ohms per cubic centimetre, and capable of carrying intermittently currents from 30 amperes to 400 amperes or higher still if necessary. The grids are usually left plain without any rust preventive.

The determination of the resistance values in any particular case is not very difficult if the motor characteristics are known. On the other hand it is extremely difficult to decide on the capacity of the resistances for a locomotive unless the conditions of service are very precisely stated. As a general rule it is impossible to lay down a set of conditions such as can easily be given for multiple-unit trains in urban or suburban service. A locomotive can be most irregular in its working. The only rule which will provide for perfect security against overheating is to make the resistances so large that continuous running on any step of the controller is possible without giving rise to excessive temperatures. There is no difficulty in meeting this condition in the case of a low-power locomotive, and there is everything in its favour. For high-power locomotives it is practically impossible to attain to this ideal on account of the space required. For such locomotives the only thing to be done is to examine each case

separately and insert as much resistance as can be conveniently disposed in the space available. It may also be necessary to take into consideration the question of forced ventilation for the resistances. On the Continent liquid rheostats have been used in one or two cases, principally for 3-phase locomotives.

With regard to control apparatus proper, such as contactors, reversers, circuit-breakers, &c., there is this to be said, that whereas in equipments for motor coaches the designs are practically determined by the requirements of multiple-unit working, no such condition necessarily applies to locomotive control apparatus. In motor coaches all the apparatus is operated by remote control through the agency of the master controller and possibly one or two auxiliary switches. In electric locomotives, although in the first instance it is often thought best to make provision for multiple-unit working, it frequently happens that such provision is abandoned or dispensed with. For example, on the New York Central locomotives, which were originally arranged with all necessary appliances for coupling two together and controlling both from a single controller, it was found that the possibility of working in this way was not taken advantage of, and the electrical couplers were permanently disconnected.

There are, of course, cases in which this provision cannot be dispensed with, for example on the 1—C + C—1 freight locomotives for the Kiruna-Riksgraensen line in the North of Sweden. These locomotives are intended for hauling mineral trains weighing 2,000 tons, there being one double locomotive in front and another at the rear of the train. Under these conditions it is important that the two locomotives should not work independently, otherwise there would be frequent cases of breakage of couplings. The control equipments are therefore specially designed so that both can be operated absolutely synchronously from the master controller in the leading locomotive, electrical connections being provided by a control cable with the usual couplers from front to back of the train.

This condition is, however, up to the present somewhat exceptional, the more usual arrangement being that the electric locomotive is a single unit suitable for hauling trains of specified weights in the same way as steam locomotives. Under these circumstances the necessity for remote control for all switchgear and apparatus constituting the control equipment is not apparent. In many cases advantage can be taken of this to arrange the main circuit-breaker and perhaps the reversers for hand operation by means of levers, hand wheels, and geared shafts. When very large units have to be dealt with, this possibility may sometimes greatly facilitate the design and construction of the apparatus. Several of the single-phase locomotives built on the Continent have been designed on this principle.

Turning now to a rather more detailed consideration of locomotive control apparatus, it must be admitted that in many cases there is nothing to distinguish the various items in the equipment from similar items in the control equipment of multiple-unit trains except size and quantity. The contactors are more numerous and are larger as is necessary to deal with the higher current. The circuit-breaker, fuses, &c., are designed on well-known lines, merely adapted to altered conditions. Various changes may, however, be noticed, particularly in the locomotives built in the United States. For example, reversers are commonly eliminated and replaced by the necessary number of contactors.

Circuit-breakers for continuous-current locomotives do not call for any special remark except that on high-voltage systems the circuit breaker must not only be substantial but should also be allowed plenty of room in which the arc may spread. Where the high-voltage continuous-current supply is distributed by means of an overhead line, it is advisable that the arc formed on breaking a heavy overload or a short circuit should not be violently disrupted by means of a strong magnetic blow-out, otherwise there is a liability for surges to be set up in the overhead line. On alternating-current locomotives, the circuit-breakers are usually oil switches similar to those used in generating stations, but adapted to fit into the locomotive.

In the past there has been very little automatic control apparatus in this country. Whatever its merits or demerits in connection with multiple-unit trains, it seems to the author that for locomotives, especially freight locomotives, there can be no question as to the benefits to be gained from taking the regulation of the tractive effort at starting out of the hands of the driver. So far as the author is aware, the only cases where automatic control is employed are on the 3-phase locomotives for the Simplon tunnel and the Italian railways. The author is strongly of the opinion that if the limit switches are adjustable, and if the control equipment can be changed over without difficulty or complication from automatic to hand control whenever circumstances require such a change, there is everything to be gained by relieving the driver of the necessity of watching the ammeter and setting him free to attend to the signals and to his other duties.

Coming now to induction regulators for controlling single-phase railway motors, the main point to which attention may be drawn is the necessity for very substantial construction. Except when the relative positions of the primary and secondary windings are such that the mutual induction is zero, there is a very considerable torque produced by the action of the magnetic field and the current in the secondary winding. Moreover this is neither a continuous nor a uniform torque. On the contrary, as there is only a single phase in the magnetic field, the force fluctuates at twice the frequency of the supply between zero and maximum values. It is clear, therefore, that a fairly powerful motor is needed to operate the regulator; and the reduction gearing between the motor and the regulator must be of a very substantial nature. Some trouble has been experienced with regulators of this type due to breakage of the gears which were designed before the effect of the powerful fluctuating torque was fully realised. Any sudden overload or short circuit in the main motors is bound to set up a tremendous force in the induction regulator, and the whole of this is transmitted to the teeth of the gear wheel.

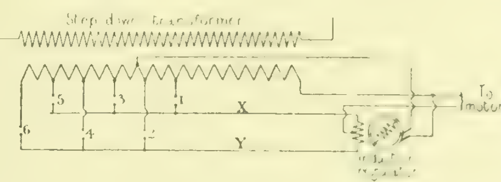


FIG. 8.

The advantages and disadvantages of induction regulators as compared with contactors has recently been considered very thoroughly on the Continent in the light of the experience acquired with the locomotives already in service for some time. The general tendency seems now to be setting towards the use of contactors exclusively for locomotives however large. This has been the practice all along in the United States and has much to recommend it. In case of a bad short circuit, protection is afforded by the main circuit-breaker, the contactors being unaffected if the circuit-breaker is capable of dealing with the short circuit immediately and effectively. In the case of an induction regulator equipment there is in addition to the demand on the powers of the circuit-breaker a very severe shock on the mechanical parts of the regulator.

Apart from this argument the time element must also be taken into consideration. The action of a contactor may be regarded as practically instantaneous, and in case of momentary failure of the supply all the contactors will open, and the control system can easily be arranged in such a way that they will not close again except by notching up from the first position of the master controller. In this way protection is provided against sudden rushes of current. With the induction regulator, or indeed with any other controlling mechanism operated by an auxiliary motor, such as, for example, the drum-type controller of the new Lötschberg single phase locomotive, similar protection can be provided, but the process is comparatively slow and cumbersome. On the other hand, the induction regulator undoubtedly possesses the advantage already mentioned of fine graduation in the regulation of the speed and tractive effort of the locomotive, which can only be obtained with contactors by multiplying the number of contactors and operating circuits and by enlarging the master controller.

Most engineers will agree that the fewer auxiliary motors there are in a locomotive the better. So far as single-phase locomotives are concerned, the supply of current at a voltage suitable for small motors is quite a simple matter, as there is usually an auxiliary transformer which can be tapped as required. With continuous-current locomotives, however, especially when the supply voltage is higher than 600 volts, the auxiliary motors must be fed either from the main supply direct, or from the dynamotor or motor-generator. In either case the voltage is probably inconveniently high for small motors. On the other hand, there is no great difficulty in insulating master controllers and contactor-operating coils for 600 or 750 volts, or in reducing the voltage on each coil by means of control rheostats. It would be a mistake, however, to press forward too much in the direction of a rigid standardisation until the general requirements of electric locomotives and their operating conditions are better known.

EFFECT OF OXYGEN ON QUALITY OF CAST IRON.*

BY J. E. JOHNSON, JUN.

THE doctrine of chemical control of the quality of pig iron met some obstacles when first presented. These were unimportant but exceedingly difficult of removal. The old school of metallurgists, who knew but little chemistry, had always insisted that there were fundamental differences in quality which were not revealed by analysis. The more ardent advocates of the newer theory of chemical control ridiculed this view. Those whose position forced them to look for the facts from whatever source derived came gradually to believe that while the theory of chemical control was in a broad way correct, there were certain facts which this theory did not cover, and that the old-school metallurgists, while wrong in many of their notions, were undoubtedly right as to this. This view now seems to prevail among those best informed on the subject.

In our search for the explanation for these discrepancies, there seemed, after the most careful consideration, to be two facts which might be taken as established: (1) That certain irons possessed a quality as they came from the furnace which was preserved on remelting, and which reappeared in castings of which these irons formed an important ingredient. (2) That the rarer elements, such as nickel, cobalt, chromium, titanium, vanadium, and the like, while not absent from the point of view of ultimate analysis, were in such small quantity and varied in ways so entirely independent of the quality of the iron that the explanation could not be attributed to them.

In spite of the certainty in our own minds regarding conclusion (1), and the amount of qualitative confirmatory evidence we had on the subject from innumerable users, we felt that there might be some hesitation on the part of others in accepting it, and we accordingly decided to make a series of tests which should, if possible, be so conclusive as to admit of no dispute. We took six irons constituting three pairs, the irons of each pair containing the same silicon (approximately), but having a different fracture and different strength, as shown by test bars cast from the furnace. The silicon of the three pairs was about 1·90, 1, and 0·70 per cent. We remelted these in twin crucibles, as will be described later, and cast test bars from the re-melts. In addition to the silicon we determined the graphitic and combined as well as the total carbon in each iron, both before and after remelting. We also made photomicrographs of the original pig and of a test bar from the re-melt, both etched and unetched, for each of the six irons.

To show quantitatively the relation between strength, combined carbon, and graphite, we made combined carbon determinations, by difference in all cases, on the 1in. bars, but the greater chilling of 1in. bars in the medium No. 3 iron threw the combined carbon far beyond the eutectoid ratio, and we did not think this constituted a fair comparison. We therefore ran the combined carbon in all the 2in. bars, taking the sample from the exact centre of the broken face of the 2in. bar, so as to make the results as nearly comparable as possible in each case. These results are shown in Table 1. In pair 1, silicon 1·90 per cent., the combined carbon in the strong iron was 0·65 per cent., and in the weak iron 0·78 per cent. The graphite in the strong iron was 3·40 per cent., in the weak iron 3·30 per cent. In pair 2, 1 per cent. silicon, the strong bar contained 0·96 per cent. combined carbon, the weak iron 1·13 per cent. The graphite was exactly the same in both, 3 per cent. In pair 3, 0·70 per cent. silicon, the combined carbon in the strong iron was 1·20 per cent., in the weak iron 1·29 per cent. The graphite in the strong iron was 2·90 per cent., that in the weak iron 3·20 per cent.

In every one of these cases it will be seen that if we take account only of the quantity of combined carbon as increasing the strength of the matrix and that of graphite as reducing the same, we shall get results exactly opposite to the actual ones, except as regards the graphite in pair 3, and even here the difference in favour of the strong iron is slight. It may be that the matrix is somewhat stronger in the strong iron, but one is forced to the conclusion that the principal reason for the difference is the shape and size of the graphite formed in the two cases, and that quantitatively this difference is ample to account for the difference in strength.

It seemed inconceivable that a quality which would survive remelting and superheating to a point well above the fusion point, as in foundry practice, should be a purely physical quality. In other words, if one iron were better than another because cast at a lower temperature, for instance, and for no other reason (both being identical in analysis); when both were remelted to the same temperature and recast under the same conditions, it is incredible that they would not lose the difference in quality due to this difference in original casting temperature. As the difference in quality evidently did persist in spite of remelting, it seemed to me necessary to believe that the difference was a chemical one.

As a consequence of this conclusion, and of the establishment to our satisfaction of the second fact mentioned, that the less common elements were not responsible for these differences in quality in general (though undoubtedly they exert marked influence in special cases), it seemed inevitable that some of the common elements, not ordinarily determined, must be accountable for these variations in quality. Of these, the most universally present in the blast-furnace, oxygen, nitrogen, and hydrogen, are the most common, and seemed a likely field for investigation.

Some metallurgists have taken the view that it was impossible for oxygen to exist in the presence of so highly carbonised a product as cast iron, and at so high a temperature as that of the blastfurnace, but about 10 years ago I had made certain observations which seemed to me to indicate strongly the presence of oxygen in cast iron, and I did all that I could to get the matter investigated then by those competent to do the work. The furnaces of the Longdale Iron Company, in whose employ I was at that time, ran continuously for many years on basic iron, with an absolutely constant ore mixture and with a blast temperature which was, to all intents and purposes, unvarying from one year's end to another, 850° Fah. Careful and long-continued observation of the appearance of the iron, and particularly of the small sample chill pig made at each cast, in conjunction with the analysis, taken with the working of the furnace itself and the character of the running iron, brought out clearly certain conditions which prevail to a certain extent at all plants, but not so conspicuously at those with less constant conditions.

Marked differences in the fracture of the iron for a given analysis were observable according to whether the iron was "wild" on irregular furnace conditions, or whether the operation was normal and the iron "quiet." On white irons, in good normal working condition of the furnace, the fracture of the chill pig was practically square, with clearly-marked acicular crystals running perpendicularly from the chilled surfaces of the pig, even from the top in some cases, and clearly showing lines running from the centre to the corners, these lines being where the sets of crystals from adjacent sides met. On a "wild" iron of similar analysis the fracture was smooth, but conchoidal rather than square, with a complete

* Abstract of paper read before the American Institute of Mining Engineers, February 18th, 1914.

absence of crystals radiating from the sides of the pig, and, of course, a corresponding absence of the interference lines of these adjacent sets of crystals running to the corners.

Irons with higher silicon when made on a smoothly-running furnace had a comparatively slight chill. Such as there was showed strongly-marked acicular crystals similar to those in the white iron, the grain quite open and the colour light. When made on a wild-working furnace, iron with approximately the same silicon had greater chill with absence of crystals, while the grey portion was exceedingly fine-grained, and dark, almost purplish in colour, so as to give it a velvety appearance.

In coke practice a wild-working furnace is almost always associated with higher sulphurs, and the irons last described, both white and grey, came to be cordially detested, as showing, even in advance of analysis, high sulphur. It is a matter of much interest to observe that the white irons showed in an increasing degree, as they became wilder, cleavage surfaces which were discoloured with the blue, red, and purple "oxide colours." This was commonly attributed to oxidation by the absorption of air into cooling cracks in the pig, but I have seen many cases where these surfaces could only be broken apart by the most tremendous sledging, and this never seemed to me to correspond with the idea of a crack of sufficient width to permit the ingress of air. These "wild" irons, particularly the harder ones, as they cooled, threw off a scale of considerable thickness, continuous at first and detaching itself from the surface of the pig in slabs frequently as large as one's hand. Thinking that this scale might be an indication of something, I had it analysed for sulphur, with the surprising result of finding only about one-third as much sulphur in the scale as was in the iron.

When I first began making charcoal iron, the founder told me of "special cylinder" iron, which he described as "an iron with a No. 2 analysis and a No. 3 fracture, made when the furnace was coming up out of a scrape." I asked to be shown a specimen of this iron, and being struck by its absolute similarity of appearance to the "wild" grey iron made on a coke furnace under similar conditions, I was at once convinced that it contained oxygen and that the notion of its superiority to ordinary iron was an erroneous one; and I condemned it without qualification.

I was strongly of the opinion then that the more easily reducible the ore the better would be the iron, because the more thoroughly deoxidised it would be. This was very strongly the opinion of the general superintendent, and he accordingly bought some Mesabi ore of first-class physical structure, containing about 7 per cent. of combined water; in other words, a fine limonite; and we made a test with this ore, substituting it for our regular Gogebic hematite, a little at a time.

We had by that time instituted the making of test bars from every cast and could observe directly the variations in the strength produced by different conditions. We found that the strength of the iron fell steadily as the percentages of Mesabi increased, so that it dropped from 2,800lbs. or 2,900lbs. on a 1·25in. test bar to about 2,400lbs. when we had on from 75 to 80 per cent. of the fine limonite. We then took off the Mesabi, got the furnace back on to an all soft-hematite burden, and repeated the experiment, with absolutely identical results.

About that time my attention was called to coke irons made on an all-limonite burden, which were of beautiful analysis, soft, open-grained, and exceedingly weak. It then occurred to me that we had disliked the "wild" coke irons because they were generally associated with high sulphur, without regard to their physical characteristics, and, on thinking it over, I realised that they were not infrequently exceedingly strong, tough irons; and, finally, it seemed to me likely that by reversing my former opinion absolutely we might perhaps get a theory which would conform more closely to the facts, and that it might be the presence of a certain amount of oxygen (in what form I do not pretend to say) that produced certain characteristics as to fineness of grain, chilling qualities, strength, and toughness, which are so much desired. It is now more than two years ago that I began to work on this hypothesis with all the means at my command.

I have previously mentioned a product virtually unknown at coke furnaces, which we call spongy No. 6. This is an iron made on an exceedingly cold furnace, perfectly white and filled with a mass of blow-holes so great as to occupy up to a half or even more of the volume of the metal. The walls of these blow-holes are as white as silver. The cause evidently is the descent into the hearth of a mass of incompletely reduced iron which, mixing with the liquid iron already present, sets up an action almost like that in an open hearth furnace. The silicon is removed down to the barest trace, 0·03 per cent. or so, and the carbon is then attacked and oxidised from the normal 3·50 to 4·00 per cent. down nearly to 3·00 per cent. in some cases. The iron, being very cold and low in carbon, is naturally very pasty, and chills without giving a chance for the escape of the CO formed by the oxidation of the carbon.

It was evident that this iron must contain a great quantity of oxygen, and that if this were really the cause of strength and the other desired qualities in iron it could be secured by making a mixture of this spongy No. 6 and a normal iron. Such a mixture was accordingly melted in the crucible, and test bars made therefrom showed results as strong or stronger than the best iron ever made from the furnace; 1·25in. round bars on 12in. centres breaking up nearly to 5,000lbs., as against an average of about 3,000lbs. for normal irons.

It then seemed that we had only to introduce oxygen into the hearth of the furnace to make an iron as good as the best. The easiest way to do this seemed to be to cause irregular working of the furnace, and this we proceeded to try out by purposely distorting the filling for several hours. We undoubtedly upset the regular running of the furnace, but the iron was no better, probably somewhat worse than before. We then put a medicine valve on the bustle pipe, filled it with mill scale, and blew it into the hearth just before cast time, with little or no result, and such as there was, a detriment to the quality. This was repeated several times.

We then began ladle experiments, heating iron ore and other kinds of oxides in the bottom of a ladle before cast time and running iron in on them at cast, stirring up the mixture and pouring test bars and sample pigs. By this means we did close up the grain of the iron and induced a paper chill (that is, a line of white no thicker than a piece of paper around the edge of the pig), which was not present in the regular cast, but when it came to improvement in strength and toughness there was little or none to be observed.

During the early part of this investigation descriptions of the Ledebur apparatus for the determination of oxygen in iron and steel as modified by the chemists of the American Rolling Mill Company were published, and we bought a set of this apparatus and began direct determination of oxygen. This determination in the presence of 3 or 4 per cent. of carbon is a very different matter from its determination in steel, and it took some time to learn all the precautions necessary to secure low blanks and concordant results. This end, however, was attained in time. We first made a determination of oxygen in some spongy No. 6 and found it to contain as high as 0·13 per cent. We then took cold-blast irons and special cylinder irons and found these to range as high as 0·07 per cent. We then took normal charcoal irons and found them to contain only about 0·015 per cent.; foundry coke irons and electric-furnace irons contained none at all. We were unable to secure samples of "wild" coke basic iron such as described.

As many of the data in this article are derived from tests of remelts, it seems desirable to state that all the remelts mentioned or tabulated in this paper are made in a "coke hole," approximately elliptical in shape, so as to take two crucibles at once, and provided with two tuyeres at opposite ends of its long diameter, so that both its crucibles would be subjected to the same intensity of combustion, &c. In all cases where directly comparative results of a given treatment have been sought, iron from the same cast has been used in each crucible, melted at the same time, and the two poured within a few minutes of each other; one with, the other

without the desired treatment. We have endeavoured to get two 2in. square bars, two 1in. square bars, and two 1·25in. round bars, all cast on end, from every such heat, but not having a skilled moulder on this rather difficult work, we have not always succeeded in getting a complete set of perfect bars. There is also, of course, a variation to be expected in these bars on account of the nature of the material and on account of their being industrial rather than laboratory or refined tests.

We repeated many times the experiment of remelting normal or even very poor ("spotted") irons with spongy No. 6, and with the same result in every instance, an improvement in the strength up to 50 per cent. or more. We give, in Table I., a summary of the results on the three pairs of remelts mentioned earlier, which shows their chemical composition and also the strength of the original iron and of the remelts. It will be seen that in every case those irons which were strong as they came from the furnace retained their superiority after remelting. It will also be seen that the good iron was in each case much higher in oxygen than the corresponding poor iron.

To summarise, therefore, we consider that we have proved the following facts: (1) Strong, tough irons of high chilling qualities contain oxygen in appreciable quantities. Weaker irons of similar analysis contain less or no oxygen. (2) Poor and normal irons may be improved beyond recognition by introducing oxygen into them.

Table I.—*Results of Remelts.*

Original Iron. Cast No.	Original Iron. Kind	Remelt No.	Breaking Strength pounds. 1·25in Round Bar	Breaking Strength pounds. 2in. Square Bar.	Total Carbon per Cent.	Graphitic Carbon per Cent.	Combined Carbon per Cent.	Silicon per Cent.	Manganese per Cent.	Phosphorous per Cent.	Sulphur per Cent.	Nitrogen per Cent.	Oxygen per Cent.	Fracture.
			3,000											
A	Soft 1...	......	3,350	....	4·00	3·22	0·78	1·90	0·62	0·139	0·017	0·006	0·027	Close grain for grade
			3,150	16,000	4·05	3·40	0·65	Sample	taken	from 2in. bar.				
A	Soft 1...	R. 291	3,200	15,900	4·05	3·05	1·00	Sample	taken	from 1in. bar.				
			2,500											
B	Spl. 1...	......	2,900	....	4·09	3·43	0·66	1·88	0·70	0·112	0·020	0·0030	0·009	Very open, low chill
			2,600	13,000	4·08	3·30	0·78	Sample	taken	from 2in. bar.				
B	Spl. 1...	R. 292	2,700	13,900	4·08	3·29	0·79	Sample	taken	from 1in. bar.				
			3,400											
C	High 2...	......	3,500	....	4·00	3·05	0·95	1·00	0·46	......	......	......	0·038	Close grain, ⅛in. chill
			3,800	16,000	3·96	3·00	0·96	Sample	taken	from 2in. 2ar.				
C	High 2...	R. 297	3,700	15,000	3·96	2·96	1·00	Sample	taken	from 1in. bar.				
			2,400											
D	High 2...	......	2,900	....	4·05	3·15	0·90	1·00	0·50	......	......	......	0·009	Open grain, no chill
			3,000	14,900	4·13	3·00	1·13	Sample	taken	from 2in. bar.				
D	High 2...	R. 298	2,800	12,000	4·13	3·16	0··7	Sample	taken	from 1in. bar.				
			3,500											
E	Med. 3...	......	4,200	....	4·10	3·50	0·60	0·70	0·60	0·128	0·035	......	0·0065	Very close grain. 0·25in. chill
				19,300										
E	Med. 3...	R. 301	4,150	20,800	4·10	2·90	1·20	Sample	taken	from 2in. bar.				
F	Med. 3...	......	2,500	....	4·49	3·60	0·89	0·72	0·59	0·108	0·024	......	0·009	Open grain, ⅛in. chill
				10,900										
F	Med. 3...	R. 302	2,750	12,900	4·49	3·20	1·39	Sample	taken	from 2in. bar.				

As an additional proof that the actual cause of the increased strength of the strong irons was oxygen, we thought it would be well to try the effect of deoxidising some of these strong irons with recognised agents used for that purpose. We accordingly made various remelts of strong irons which we deoxidised in the crucible immediately before pouring with aluminium in several cases and with titanium in one or two. The results with titanium are confirmatory of the results with the aluminium. The strong irons deoxidised with about 1oz. of 10 per cent. ferro-titanium per 50lbs. crucible were greatly weakened. We believe that these results may be taken as a final and conclusive proof that oxygen in some form not known or understood by us is accountable for the abnormal strength of irons whose analysis as regards other elements is normal.

As to the condition in which this oxygen exists, we know nothing. We have been unable to detect it with the microscope, and we can only assume that it is some oxide of very much lower degree than any with which we are familiar. Its effects seem to be two-fold: (1) It makes the iron very much more sensitive to chilling influences. One of these good irons if cooled normally will be only slightly harder than a normal iron, and on account of its fine, close grain will machine beautifully: but if the surface be chilled even slightly it begins to whiten up, and with a chill of any strength will be solid white at the edge, where a normal iron of the same silicon would show little chill, or none at all. (2) The other principal effect consists in the extremely fine sub-division of the graphite in the strong irons, contrasting conspicuously with the large, coarse aggregates of graphite in the weak irons. A comparison of the photographs obtained of the strong irons with those of the malleable iron cast white and graphitised by annealing, one is struck with the resemblance, and it is easy to suppose that the effect of oxygen is to raise the solidifying point of the iron relative to the temperature of evolution of the graphite, so that the latter, instead of being free in the liquid mass to assume as bulky a form as it chooses, can only form against great pressure, and must therefore form in the most compact particles possible, which, in turn, cannot coalesce into larger masses because of the resistance of the surrounding medium. These are purely scientific points outside the field of a commercial investigation, and beyond our power to investigate.

Conclusions.

(1) Irons which contain oxygen to a considerable extent, in a form as yet unknown, are stronger and tougher and have better chilling qualities than irons containing less of this element, but of the same analysis in other respects.

(2) Irons may contain a sufficient quantity of carbon to make them rotten and worthless through the predominance of the eutectic structure when deficient in oxygen, and yet, when they contain a considerable quantity of oxygen, be entirely free from this structure and of excellent quality.

(3) Furnace conditions control whether the carbon shall be below or above the eutectic ratio and the presence of much or little oxygen, the two dominant factors in the fundamental quality of the iron; that iron, broadly, being the best which is made at the lowest temperature.

(4) Charcoal irons can be made at temperatures several hundred degrees lower than are practicable with coke, and have a great possible advantage in that respect. This is largely wasted without good furnace work in the broadest sense.

(5) Phosphorus up to 0·50 per cent. or more exercises a beneficial influence on the strength of the iron and the depth and character of the chill. Phosphorus also has a tendency to reduce total carbon.

(6) Aluminium and titanium tend to reduce the strength and chilling power of the iron by removing its oxygen, but titanium may have an influence independent of this on account of its removing nitrogen also.

(7) Chromium and manganese have an almost identical effect in raising the total carbon and throwing it into the

combined condition. The latter increases the chill and the strength, but the combined carbon so produced is in the form of eutectic plates, which deprive the iron of much of the strength which it would have with the same combined carbon in the absence of these plates.

(8) Chill produced by these elements cannot be expected to have the same wearing qualities as that produced by elements which do not further the formation of flat plates of eutectic.

BLASTFURNACE AND COKE-OVEN GAS FOR POWER PURPOSES.*

BY HEINRICH J. FREYN.

By taking advantage of the recent innovation of H. A. Brassert, blastfurnaces are now able to ensure fulfilment of a contract for the delivery of a specified uniform amount of power in times of business depression as well as activity. Brassert virtually transforms a non-active blastfurnace into a huge gas producer, and gasifies in it, small coke, raw coal, and coke breeze, on the principle of a slagging type of producer, using open-hearth slag as flux. This has been very successfully demonstrated at South Chicago and Gary. This disposes of the argument that curtailment of pig iron and coke production in times of business depression militates against maintaining, say, a gas-driven electric power plant.

The blastfurnace gas engine has to-day attained a very high standard, as can readily be seen by the truly remarkable results achieved with the world's largest gas-engine plant at Gary; but the coke-oven gas engine, although mechanically equivalent to the blastfurnace gas engine, has to deal with a fuel of entirely different character. The large percentage of hydrogen in coke-oven gas causes an extremely rapid flame propagation, so that the time of combustion of a mixture of coke-oven gas and air is considerably shorter, and this combustion much more of an explosive character, than is the case with blastfurnace gas. The compression in coke-oven gas engines must, on account of these characteristic qualities of the fuel, be kept considerably lower than is customary and appropriate for blastfurnace gas engines. Costly experience has taught European gas-engine manufacturers to reduce the compression pressure in coke-oven gas engines to 110lbs., and even to 85lbs., per square inch, depending somewhat on the percentage of hydrogen in the gas.

Owing to the snappy action of the gas, coke-oven gas engines are at times quite susceptible to back-firing and premature explosions. Effective cooling of gas cylinders, pistons, piston rods, &c., becomes, therefore, a very important matter on account of the intense heating of these parts. The absolute quantities of coke-oven gas consumed during one working cycle are comparatively small, even at full load, and perfect regulation of coke-oven gas engines is, therefore, not so easily accomplished as that of blastfurnace gas engines. Serious difficulties were encountered in the earlier days because it was found quite impossible to maintain satisfactory parallel operation, especially at fractional loads, of coke-oven gas-engine generators feeding into the same system. Ignorance on the designer's part was very largely responsible for these difficulties, because gas ports and gas-valve areas were made far too large and entirely out of proportion to the size of the air ports, since no attention was paid to the low specific gravity of coke-oven gas. Much larger quantities of gas than actually required at any specific load were thus caused to enter the gas cylinders, and these earlier engines nearly always operated on excessively rich mixtures. The obvious result was, after burning, destruction of exhaust valves, piston rods, and cylinders, violent back-fires and vicious premature explosions, all of which caused extremely unsatisfactory commercial operation.

To-day the coke-oven gas engine has reached such a high state of perfection in Germany that it is second only to the blastfurnace gas engine in importance and serviceableness, with the qualification, however, that unit capacity, and more particularly the rating, must be conservative. The latest coke-oven gas engines built by Thyssen & Co., of Muelheim Ruhr, Germany, installed at Bonifacius Colliery, in Westphalia, are of the twin tandem double acting four cycle type, having four gas cylinders 47½in. diam., 51in. stroke, and develop at 94 revs. per minute about 5,000 b.h.p. Parallel operation is beyond criticism and the load factor of these engines is very high—from 90 to 100 per cent.—since peak loads are taken up by the blastfurnace gas engine plant and the steam turbines. These engines were built two years ago and are probably the largest coke-oven gas engines in the world. The compression pressure is only 85lbs., and the maximum explosion pressure does not exceed 250lbs. per square inch. Each cylinder end is provided with three igniters. The gas consumption, as measured by means of a large gasholder, was found to be 12,000 b.t.u. per kilowatt hour at 90 to 100 per cent. load. The over-all mechanical efficiency, including generator, is 82·3 per cent. at that load.

The overwhelming majority of gas-engine manufacturers in this country restrict the capacity of coke-oven gas engines to about 700 b.h.p. or 750 b.h.p. per double-acting cylinder at present. This prudent and conservative policy on the part of American gas-engine builders shows excellent judgment.

It should be remembered that the presence of sulphur in coke-oven gas in the form of sulphuretted hydrogen and carbon bisulphide was the cause of very serious troubles before it was learned how to combat its influence. The slightest water leak in the gas cylinders from defective pistons or water-cooled exhaust valves resulted in serious corrosion of all finished parts, and particularly of piston rings, piston rods, and metallic packing. This corrosion was caused by sulphuric acid formed by the combination with oxygen and water of sulphur dioxide, resulting from the combustion of sulphur in the gas. Instead of striking at the root of the evil by proper sulphur purification, and by prevention of water leaks, attempt was made to cure the trouble by resorting to building materials which would not be attacked by sulphuric acid.

Considerable progress has been made in recent years in designing sulphur cleaning plants which eliminate nearly all of the sulphuretted hydrogen, although no practical means has so far been discovered to separate carbon bisulphide from the gas. Gas-engine manufacturers in Europe are, however, willing to guarantee satisfactory and continuous operation of gas engines supplied with purified coke-oven gas containing as much as 1·25 gr. of sulphur compounds in one cubic foot.

Naphthalene, which is deposited by the gas, particularly in cold weather, easily obstructs pipe lines and valves. This also has been the cause of much annoyance. If benzol is recovered from the gas no trouble from naphthalene deposits can occur, since it is absolutely necessary for efficient benzol recovery to extract the naphthalene from the gas. In plants where benzol is not recovered, it happens not infrequently that the gas pipes, &c., have to be steamed out from time to time in order to dissolve the naphthalene, which otherwise accumulates in the piping and on the valves, until the output of the power plant is noticeably reduced. Incidentally benzol recovery, in connection with by-product coke-oven plants, improves gas-engine operation owing to the elimination of certain hydrocarbons, and because the heating value of the gas is reduced about 5 per cent. Coke-oven gas used for power purposes, or as fuel in a steel plant, does not require any illuminating properties; the recovery of the benzol from the gas for sale offers very attractive financial possibilities and yields an exceptionally handsome profit on the investment.

A straightforward acknowledgment of the salient difficulties with earlier coke-oven gas engines coupled with an account of the remedies which eliminated the trouble in subsequent installations can only have a beneficial effect upon the cause of the coke-oven gas engine. The meagre experiences obtained with one or two earlier coke-oven gas engine installations in this country are, in the author's judgment, not sufficient premises to argue for or against the use of coke-oven gas for gas-engine purposes and to draw conclusions of any value.

The application of the coke-oven gas engine for direct

* Abstract of paper read at the New York Meeting of the American Institute of Mining Engineers, February 18th, 1914.

driving of rolling mills is, to the author's knowledge, not illustrated by a single installation abroad or in this country. Its absence from this field is largely explained by the geographical separation of coke-oven plants and rolling mills. The load conditions of rod, wire, and sheet mills are not unfavourable for direct gas-engine drives, since they impose upon the prime mover, neither violent nor excessive load variations. The average power demand of such mills is moderate, so that frequently single-tandem gas-engine units are fully capable of performing the work. The direct-connected rolling-mill gas engine for light continuous mills does not require much overload capacity, and can therefore be suitably rated to operate at a high load factor. The gas consumption is then very low and the thermal efficiency high. The result is a substantial fuel economy per ton of finished product, compared with steam-engine, steam-turbine, or electric-motor drives.

The principal advantage of direct gas-engine mill drives is, of course, the saving in cost of installation and operation. Such direct drives do away with costly combinations of electric central station, transformers, transmission lines, mill motors, and the requisite expensive auxiliaries. They are, moreover, not attended by the multiplicity of efficiency losses on account of the roundabout way of generation, transformation, and transmission of energy, which are handicapping electric mill drives.

Blastfurnace gas of low heating value and great volume does not lend itself readily to economical long-distance transportation through pipe lines, because the first cost of compressor equipment and pipe line would alone be prohibitive, but the transmission of coke-oven gas for illuminating purposes through distances of 30 and 40 miles is not unknown, and the expenses incidental to the installation and operation of booster stations are moderate.

No matter what objections could justly or unjustly be raised against the use of coke-oven gas for direct power generation in modern gas engines, none of these can possibly apply on the use of a mixture of blastfurnace and coke-oven gas. The practice of combining blastfurnaces, steel mills, and coke-oven plants in one locality, gives the American iron and steel master an enormous advantage over the majority of his European competitors in the matter of rational utilisation of the available surplus gases. It is evident what truly ideal conditions would obtain in such combined plants if only one kind of gas fuel were used for all requirements of the plant. A gas mixture in suitable proportions of blastfurnace and coke-oven gas would fulfil the most exacting specifications which could be imposed.

There would not be any difficulty in maintaining a heating value of the gas mixture to all intents and purposes uniform, if this task were committed to the action of automatic devices. One, or, if necessary, several automatic recording gas calorimeters could be equipped with a maximum-minimum electric-contact attachment, corresponding to the permissible maximum and minimum heating value of the gas mixture. These calorimeters would control—by means of relays and electric motors—gate or butterfly valves, arranged in the coke-oven gas pipe, at or near the point of connection with the blastfurnace gas main. The suggestion of using a gas mixture for gas-engine purposes is by no means new or original, with the exception perhaps of the proposed method of controlling the heating value automatically. Gas-engine plants using such mixtures have been in very successful operation abroad for a number of years. A mixture of one part of coke-oven gas of 500 B.T.U. and of 15 parts of blastfurnace gas of 100 B.T.U. would have a heating value of 125 B.T.U. per cubic foot.

The fact that the gas mixture is supplied by two practically independent sources constitutes in itself a safety factor of no little value. At times of momentary shortage of either ingredient the regular output of electric power would be maintained by admitting to the engines a mixture leaner or richer than standard. The possibility of using in the engines producer gas made by one of the existing blastfurnaces operating according to Brassert's gas-producer principle is an adequate safeguard against the influence of a curtailment of pig iron and consequently blastfurnace gas production brought about by a business depression. Blastfurnace producer gas has about the same heating value as the gas mixture and its composition by volume is approximately as follows:—

Blastfurnace Producer Gas.

	Per cent.
CO	34·0
CO_2	1·6
H	2·9
CH_4	1·0
B.T.U.	126

The percentage of hydrogen in furnace-producer gas is considerably smaller than in the standard gas mixture. The former gas can, therefore, be substituted for the mixture with impunity. The higher percentage of carbon monoxide in the producer gas will counterbalance the reduction in hydrogen to a large extent, as far as the effect upon gas-engine operation is concerned. It can thus be expected that the change from one gas to the other can be made even without important readjustments of valve and damper setting on the gas engines.

INDUSTRIAL AND TRADE NOTES.

The Dalby-Watson Optical Indicator.—Messrs. W. Cussons, Ltd., the Technical Works, Lower Broughton, Manchester, inform us that they are the makers of the optical indicator described on page 235 of our last week's issue.

Revision of Riveters' Price List.—A two-days' conference between the Shipbuilding Employers' Federation and the Boilermakers' Society on the revision of the riveters' price-list, which the men contend to be out of date, concluded at Edinburgh on the 12th inst. At the close it was officially intimated that both parties had come to a mutual agreement, and that the terms would be submitted to their members as early as possible; meantime, the notices on the Tyne and the Wear were suspended, and work will continue.

Boiler Makers' Society and Political Action.—In the case of the Boilermakers' Society two ballots have been necessary to determine whether the Society will engage in political action under the Trade Unions (No. 2) Act—one to sanction the necessary amendment of rules and the other on the general question of a political levy. The first ballot has just been completed, and the result is officially declared as follows: For alteration of rules, 2,764; against, 1,542; majority, 1,222. The present membership of the Society is 66,000, so that over 61,000 members did not vote. The second ballot to authorise the necessary levy will be taken next month. It will be remembered that last year the boilermakers decided to secede from the Labour party.

New Motor Ship.—The twin-screw motor vessel "Falstria" was launched on the 12th inst. by Harland & Wolff at their Glasgow shipyard. The "Falstria" is the first of two sister vessels which are under construction by the same builders for the East Asiatic Company, of Copenhagen. In length over all she is 381ft., in breadth moulded 50ft., and in tonnage about 4,500 gross. The winches and windlasses are electrically operated, and the steering gear is arranged on the electric hydraulic principle. The vessel will be fitted with two 4-stroke-cycle single-acting Diesel motors, each coupled direct to its line of shafting; also two 4-stroke-cycle single-acting auxiliary Diesel motors, each coupled direct to a dynamo and an air compressor. Each of the main motors has six cylinders.

Safety Committees of Workmen.—A plan has been formulated in the State of Washington to prevent accidents in mills and factories. As a result of negotiations between the Industrial Insurance Commission and the State labour department safety committees of workmen are being organised in all plants in the State. These committees will consist of three workmen whose duty it will be to receive reports from other employés as to defects in machinery or other dangerous conditions, and as to carelessness on the part of other workmen, as well as to do safety work on their own initiative. Statistics of the Industrial Insurance Commission indicate that less than 3 per cent. of all accidents are due to unsafe machinery, the majority resulting from carelessness. It is hoped to reduce these largely by the new plan.

Employment in the Engineering Trades.—According to the return issued by the Board of Trade, employment in February was good on the whole. The coal-mining, engineering, and shipbuilding trades continued well employed. In most of the other principal industries there was also a slight improvement. The changes in rates of wages which came into operation in February

affected 50,000 workpeople, of whom 7,000 received increases and 43,000 sustained decreases, the net result of all the changes being a decrease of £1,300 per week. The decreases were confined to the iron mining and pig iron and iron and steel industries. The total number of workpeople involved in all disputes in progress during the month was 62,943, as compared with 61,783 in January. The estimated total aggregate duration of all disputes during the month was 827,300 working days, as compared with 694,800 in January.

The Trades Disputes Act.—At the recent annual meeting of the Association of Chambers of Commerce of the United Kingdom, considerable discussion was aroused by a resolution submitted by the Leeds Chamber with reference to the amendment of the Trades Disputes Act of 1906. The resolution recommended that the Act should be amended in two directions, viz., (1) by limiting the number and powers of pickets, and (2) by applying the ordinary law of agency, with proper limitations, to acts committed by or on behalf of trade unions. The Government was urged to take immediate legislative action in the desired direction. On behalf of the Dudley Chamber, a resolution was passed, which urged that "in order to avoid strikes and facilitate a speedy settlement of disputes between operatives and employers as to hours and condition of labour and wages labour tribunals on the lines of the existing labour conciliation and arbitration boards should be established in industrial centres."

Foreign Competition and Labour in Locomotive Shops.—Mr. Hugh Reid, who presided at the annual meeting of the North British Locomotive Company, held at Glasgow on the 12th inst., made a statement with regard to the outlook as to foreign competition and labour. In lamenting a much reduced output from the workshops, both in value and bulk, he said the directors earnestly trusted the workers would, in view of the aggressive continental and American competition, settle down to steady work before their markets were permanently lost to them. Within the last two years their foreign competitors had built about 212 locomotives for markets which were formerly practically theirs exclusively. All these engines could quite comfortably have been built in British locomotive shops in the time required, in addition to the work produced these last two years, if the workmen had only maintained their former output. Meantime, the prospects for the coming year were satisfactory, although enquiries for locomotives at present were few and far between.

Trade Circulars.—We have received trade circulars and catalogues from the following firms: J. W. Brooke & Co., Ltd., engineers, Lowestoft, new edition of their marine motor catalogue with one, two, three, or four cylinders, and ranging in power from 3 h.p. to 300 h.p. The Benjamin Electric, Ltd., Rosebery Avenue, Laystall Street, London, E.C., catalogue of Benjamin lighting specialities in the shape of lamps, reflectors, holders, and other supplementary fittings. The General Electric Company, Ltd., Queen Victoria Street, London, E.C., illustrated price-list of half-watt lamps for exterior and interior lighting. Nevilles, Ltd., James Street, Liverpool, illustrated pamphlet descriptive of universal angle bending machine for angle sections or tubes. Messrs. Fredk. Mountford, Ltd., of Fremo Works, Granville Street, Birmingham, a comprehensive list of their specialities, including light portable loose tool stands, taper pins, cotters, bolts, nuts, and engine, machinery, and dynamo oils. The firm specialise in quite a number of directions, and will be pleased to forward their list to any of our readers on application.

Launch of a Large Oil-tank Steamer.—There was launched on the 12th inst. from the Jarrow shipyard of the Palmer Shipbuilding and Iron Company, Ltd., the oil-tank steamer "San Melito," one of the 10 large vessels constructed to the order of the Eagle Oil Transport Company, Ltd., of London. The vessel has an over-all length of nearly 550ft., and will carry a total deadweight of 15,000 tons. She has been constructed on the Isherwood system of longitudinal framing, and under Lloyd's special survey for the carriage of oil in bulk. The oil is carried in 12 main compartments, and a special expansion trunk is provided between the main and upper decks, and extends for the full length of the oil compartments. The boilers are arranged for burning oil, the necessary supply of liquid fuel being carried in a large cross-bunker aft, a deep tank forward, and at the sides of the main expansion trunk in order to facilitate the trim of the vessel as fuel is consumed. The ventilation throughout is mechanical, and special arrangements are made to ensure safety in connection with the oil-burning apparatus. The vessel is primarily intended for the carriage of liquid fuel, but benzine and other light oil can be carried if required. The Marconi wireless system will be fitted on the vessel. The machinery has also been constructed by the Palmer Company, and comprises a set of quadruple expansion engines, balanced on the Yarrow Schlick and Tweedy system, steam for which is supplied by four large single-ended boilers arranged for burning liquid fuel on the Wallsend Howden patent system, and working under forced draught at a pressure of 220lbs. per square inch.

Railway Anomalies.—At the sitting of the Royal Commission on Railways, held in London on the 13th inst., some interesting statistics were given by Mr. W. Cunningham, of Dunfermline, to prove that there was great waste in the way British railways were managed. The average train load of passengers was, he said, 38·5 against 79·95 for the rest of the world, and, taking all classes including excursions, the fare was 0·98d. per mile, whilst for the rest of the world it was 0·72d. per mile, and the cost of goods and minerals was 1·25d. per ton per mile, against 0·78d. in the rest of the world. He estimated the British public was paying £23,500,000 a year more than the rest of the world for similar service. Giving instances of varying rates, he said that if goods were sent from Dunfermline to London or Tilbury Dock for shipment the rate was 40s. per ton, but if the things went to Tilbury Town the rate would be 76s. per ton. Glasgow, which was 30 miles nearer, had to pay a rate of 76s. 8d. against 40s. for Dunfermline. The rate for fish from Grimsby to Huddersfield was 35s. 6d. not delivered, but from Grimsby to Bradford, the same distance, was 19s. 2d. delivered. The number of men employed in Great Britain per mile of railway was 26·03, Belgium 22·95, Germany 18·99, and for the rest of the world 11·12. That was largely due to there being 1,400 directors, 4,000 clearing house clerks, and 10,000 canvassers. Continuing, he said that the nationalisation of the railways would clear the streets of competing carriers, would reduce the number of stations, and would enable better wages to be paid to the fewer men employed.

Electrolytic Treatment of Lead Poisoning.—At a recent meeting of the Royal Society of Edinburgh, a lecture on "The Electrolytic Treatment of Lead Poisoning" was delivered by Prof. Sir Thomas Oliver, M.D. He pointed out that while the number of notified cases of lead poisoning in the country was diminishing, there had been no corresponding decrease in the number of deaths, which had rather increased. In various forms lead was used in over 120 trades, and the subject was therefore important. Lead, in the form of dust, entered the system of the workmen by the skin, the alimentary canal, and the respiratory organs, and its effects were seen on the blood-making organs. Paralysis followed and sometimes blindness. The lecturer then explained a new method of treatment which had been devised by himself and Mr. T. Maltby Clague, known as the double electric bath treatment, which is being employed with remarkable success in leadworks. The men immerse their feet in a bath of water in which is fixed an aluminium grid. The hands are placed in a similar bath also containing an aluminium grid, and the current from an 8-cell accumulator is turned on. The effect of the current is to ionise the lead in the tissues of the persons operated on, and thus to drive it from one pole to the other, with the result that persons suffering from lead poisoning show no signs of it after a week or two, while a bath once or twice a week prevented the lead settling in the system. The time occupied by the bath is about half an hour. Its efficacy was shown by experiments which the lecturer conducted in the removal of lead from animal tissues, and he had succeeded in removing from the spinal cord four-fifths of the total amount of lead injected.

METAL QUOTATIONS.

TUESDAY, MARCH 17TH.

Aluminium ingot	86/- per cwt.
,, wire, according to sizes, &c. ......from	112/- ,,
,, sheets ,, ,, ... ,,	112/- ,,
Antimony	£27/10/- to £29/10/- per ton.
Brass, rolled	7¼d. per lb.
,, tubes (brazed)	9⅝d. ,,
,, ,, (solid drawn)	8⅛d. ,,
,, ,, wire	7⅜d. ,,
Copper, Standard	£63/12/6 per ton.
Iron, Cleveland	50/6 ,,
,, Scotch	56/6 ,,
Lead, English	£20/5/- ,,
,, Foreign (soft)	£20/-/- ,,
Mica (in original cases), small	6d. to 3/- per lb.
,, ,, ,, medium	3/6 to 6/- ,,
,, ,, ,, large	7/6 to 11/- ,,
Quicksilver	£7/10/- per bottle
Silver	26 13/16d. per oz.
Spelter	£21/7/6 per ton.
Tin, block	£173/15/- ,,
Tin plates, I.C.	13/- per box.
Zinc sheets (Silesian)	£24/15/- per ton
,, (Stettin; Vieille Montagne)	£25/2/6 ,,

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1912.

Storage of fuel oil. Jack. 19613.
Governing of internal combustion engines. De Rusett. 19761.
Furnaces of steam generators. Cass. 23984.
Rotary internal combustion engine. Bricknell, Bricknell, and Bricknell. 26662.
Internal-combustion motors. Von Ditmar. 27071.
Carburetters for internal combustion engines. Brown, and Brown and Barlow, Ltd. 29440.
Making of expanded metal. Chess. 29485.

1913.

Hydraulic engines. Proctor. 4269.
Non return valves. Scarborough. 4347.
Slide valves for locomotive and other steam engines. O'Donnell. 4483.
Chain-link belts. Spicer. 4489.
Clutch mechanisms, applicable for variable speed gearing. Barnes. 4748.
Catch gear of lifting and lowering apparatus. Wales. 4750.
Adjustable spanners. Fleck. 4772.
Steam superheaters for locomotive boilers. Gresley. 4837.
Construction of gear wheels. Brampton & Richmond. 4888.
Metal wheels. Challiner. 4889 and 5398.
Manufacture of artificial fuel. Blumberg. 4909.
Locomotives. Vulcan-Werke Hamburg und Stettin Akt.-Ges. 4928.
Pneumatic ejectors. Bowden Smith. 4947.
Fuel injection devices for internal combustion engines. Cross. 4950.
Machine for manufacture of foundry moulds. Mills & Ferrier. 4988.
Apparatus for testing coal or ores. Habets & France. 4992.
Carburetters for internal combustion engines. Crouan. 5121.
Ropeways. Donald. 5449.
Detectors of combustible gases. Philip & Steele. 5467.
Foundry moulding machines for pipes. Ardelt. 5994.
Tube bending machines. Ruckstinat. 6021.
Pneumatic percussive tools. Arthur. 6244.
Feeding of fuel in internal combustion engines. Roots. 6477.
Paraffin vaporiser. Bryant. 6528.
Turbo compressors and turbines. Churchill Shann. 6692.
Driving belt. Lycett. 7279.
Turbine plant. Croft. 7623.
Elastic fluid turbines. Warwick Machinery Company (1908). 7697.
Liquid fuel for internal combustion engines. Terry. 7807 and 7808.
Condensers for distilling apparatus. Oekel. 8110.
Motor vehicles. Holland. 8227.
Means for operating change speed gearing. Peterson. 8337.
Concentrating and separating machines for ores. Richardson. 9048.
Trunk pistons. Spence. 10435.
Lubrication of internal combustion motors. Medinger. 10667.
Ingot moulds. Bradford. 10821.
Motor cylinders. Allegemeine Elektricitats Ges. 11034.
Air and other non explosive gas engines. Bowden Smith. 11381.
Metal furnace. Hall. 11843.
Rock or coal drilling apparatus. Brown. 12686.
Liquid fuel spraying devices. Hamill. 12707.
Thermo couples for pyrometry. Paul. 12708
Taper turning attachments for capstan and automatic lathes. Price. 14077.
Rotary reciprocating poppet valves for internal combustion engines. Curran & Thomas. 14584.
Valves of internal combustion engines. Fielding. 15129.
Constant pressure internal combustion engines. Schmidt. 15474.
Reversing valves for furnaces. Olig. 16440.
Process of burning solid fuel. Glasgow. 16910 and 16911
Smoke consuming fittings for furnaces. Stirling. 17895.
Carburetting apparatus for internal combustion engines. Lynn and Vieira. 18162.
Vapour or steam condenser. List. 18588.
Propelling and steering mechanism for vessels. Steckemann. 18803.
Wrenches. Dickinson. 19168.
Means for the distant control of valves. Shaw. 19507.
Variable speed and reversing gearing. Nettleton. 19661.
Pipe joints. Kelleher. 19993.
Nut locks. Maxwell, and Maxwell Nut Lock Company. 20777.
Dry ore separators. Bonson. 20831.
Two stroke cycle internal combustion engines. List. 21205.
Safety appliance for lifts. R. Waygood & Co., and Carey. 21218.
Apparatus for indicating speed and registering distance of ships. Star. 21241.
Marine cableways. Miller. 21891.
Check feed valve for marine boilers. Green. 22191.
Ball bearings. Salmson, Canton, & Unné. 22991
Furnace grates. Wade. 24164.
Piston rings. Campbell & Banks. 24215.
Centrifugal blowers. Homersham. 24233
Fluid actuated reciprocating engines. Brantingham & Brantingham. 24442.
Nut locks. Ludwick & Miller. 25186.
Ball bearings for radial and axial pressure. Söderlund. 25278.
Conveyers for use in coal mines. Bowman & Jackson. 25367.
Metallurgical furnaces. Williams. 26218.
Apparatus for injecting fuel into cylinders of oil engines. Freitag. 27134.
Annealing vessels. Romer. 29392.

1914.

Apparatus for bending tubes. Ruckstinat. 241.
Cylinders for internal combustion engines. Junkers. 578.

ELECTRICAL, 1912.

Illuminating devices. British Thomson Houston Company, and Wheat. 21485.
Telephone systems. Derriman. 26782.

1913.

Electric switches. British Thomson Houston Company, and Heath. 1599.
Arc light carbons. Ayrton. 1775.
Automatic electric switch. Bigge & Butt. 1927.
Telephone systems. Automatic Telephone Manufacturing Company. 4499.
Starting switches for alternating current induction motors. Siemens Brothers Dynamo Works, Ltd., and Rodgers. 4507.
Electric ignition systems for internal combustion engines. Ketter ing. 4508.
Selective electric signalling. Harrison & Jacobs. 4584.
Section insulators for overhead conductors. Ramsey & Maley. 4931.
Electrically governing speed of engines at sea. Fithian. 5763.
Electric insulators. Browalski. 7382.
Enclosed electric switches. Hope. 7918.
Electric contacts and switching or contacting apparatus. Soc. Anon. des Etablissements L. Bleriot. 9592.
Transmission systems for electric telegraphs. Thompson. 9624.
Means for electrically indicating or counting revolutions of shafts. Siemens Bros. & Co., and Hird. 12437.
Multi pole ignition magneto with rotary field magnet. Neufeldt and Kuhnke. 12956.
Cooling of apparatus built in connection with an electric motor. Akt. Ges. Brown, Boveri, et Cie. 13610.
Electrical switches. Lundberg & Pegg. 14188.
Windings for dynamos. Siemens Bros. Dynamo Works, Ltd. 14380.
Magnetic separators. Fried. Krupp Akt. Ges. Grusonwerk. 14426.
Regulating relay devices. Maschinenfabrik Oerlikon. 15060.
Charging and discharging of electrical condensers. Mellersh-Jackson. 15284.
Variable speed dynamos. Brooks & Holt. 15686.
Electro motors for portable drilling machines. Campbell. 16428.
Means for operating electrical switches. Drysdale, and Displayer Company. 16609.
Trolley heads for overhead traction systems. Underwood. 16705.
Electric glow lamps. Siemens and Halske Akt.-Ges. 17416.
Polyphase alternating current commutator motors. Alexanderson. 19517.
Selector switches for telephone systems. Sterling Telephone and Electric Company. 19592.
Recording galvano meters. Paul Braun & Co. 20796.
Process for the electrolytic deposition of metals from solutions containing same. Hybinette. 22744.
Electrolytic process for extracting copper from ores. Hybinette. 22745.
Electrical relays. Siemens Bros. & Co. 22902.
Transformers. Siemens Schuckertwerke Ges. 24117.
Electric welding apparatus. Yount, Finigan, & Brannaman. 24472.
Mounting switches in boxes. Sclater. 24809.
Electrically driven vehicles. Siemens Schuckertwerke Ges. 27472.



An Illustrated Weekly Journal. Vol. 33, No. 844.

Edited by
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Telegrams: "Scientific," Manchester.
Telephone No. 6055 City.

SUBSCRIPTION RATES.

United Kingdom: 12/6 per annum, post free.
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21/-* „ „ Thick „
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Cheques and Postal Orders should be made payable to the Scientific Publishing Company, and forwarded to our Manchester Office, 53, New Bailey Street.

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Nomenclature of Non-ferrous Alloys.

It will be remembered that in the early part of 1912 Dr. W. Rosenhain drew attention in a paper before the Institute of Metals to the indefinite, and even misleading, character of the metals designated as brass, bronze, gunmetal, &c., in the engineering trades. These cover such a variety of alloys and differ so widely in chemical composition and physical properties that the bare use of these names results not only in confusion but sometimes in serious disputes. When the above terms were first introduced they did, to a large extent, convey fairly definite meanings. Brass, for instance, was generally understood to imply an alloy consisting principally of copper and zinc, while bronze was one of copper and tin, copper being the principal ingredient of both. It was the adulteration of bronze alloys, and the clear definition by Army authorities of the composition of bronze used in guns, that led to the evolution of the term "gunmetal" as a specific bronze consisting of 9 of copper and 1 of tin. The demands of mechanical and electrical engineering, and the greater attention given to the study of non-ferrous alloys during the last quarter of a century, combined with commercial considerations, have resulted in the production of a host of alloys differing widely in their characteristics and called not only for great discrimination in their use but for descriptive names that will more accurately describe their composition.

The simple nomenclature that formerly sufficed is now inadequate. The difficulty is to design names which shall be simple and at the same time approximate to scientific accuracy without coming into violent collision with the terms of brass and bronze, which have acquired a workshop currency through long usage, and which it would be very difficult to displace. At most a nomenclature such as proposed can only express composition in general terms, as the constituents even of binary alloys permits of innumerable variations, and it

three elements are involved the possible variations are very great. Exact definition is easily secured in any case by stating the proportions of each element, and this must of necessity be the language of specification where close adherence is required. But apart from this descriptive phraseology nowadays calls for something more comprehensive than "brass" and "bronze," which, as indicated, have almost ceased to possess any rational meaning. While Dr. Rosenhain's suggestions met with general approval, it was felt that the subject required careful consideration, and a committee was eventually appointed by the Institute consisting of eight members of the Council, along with representatives from the other leading engineering institutions, to discuss the whole question. The first report was presented at the meeting held last week. In a general way the committee have adopted the system suggested by Dr. Rosenhain, and if it is a little cumbersome, it is at all events rational, and if adopted by writers and teachers generally who deal with alloys, will doubtless permeate the ranks of those more intimately concerned, and in this way gradually secure general adoption. The scientific basis underlying the nomenclature proposed consists in denoting any alloy by the names of its component metals placed in the order of increasing numerical importance from the point of view of chemical composition by weight. The practical application of the system will be easily understood by a reference to the following examples:—

Composition of Alloy.	Proposed Systematic Name.
Zinc 30%, copper 70%	Zinc-copper
Tin 10%, copper 90%	Tin-copper
Tin 1%, zinc 29%, copper 70%	Tin-zinc-copper
Aluminium 8%, copper 92%	Aluminium-copper
Copper 3%, aluminium 97%	Copper-aluminium
Tin 32%, lead 68%	Tin-lead

While this system is simple and rational, it is somewhat clumsy when more than three metals are concerned, and, as the committee point out, creates difficulties if impurities are present in notable amount, while it does not differentiate in the case of alloys containing two metals in equal proportions. It is proposed to overcome these objections by the following extensions of the system: Where an alloy consists of more than three metals the systematic name is restricted to the three largest constituents, and the presence of others indicated by the prefix "comp" or "complex," while if the alloy contains an intentionally added element which, though small in quantity, imparts a distinctive character, that may be named first. As an imaginary example, say an alloy consists of aluminium 75, tin 15, arsenic 4, cobalt 3, iron 2·75, and indium 0·25, and assuming the special qualities due to the presence of the last-named element, the alloy would be denoted as "indium complex tin-aluminium." The name, it is true, is long, but it is an extreme case, and it does at least indicate that tin and aluminium are the main ingredients, though combined with other metals, and that indium imparts special properties. This alloy might be characterised as a binary one, but when a number of metals are concerned, and the diminishing proportions of the constituents are less pronounced, it might be difficult to say whether it should rank as a binary or a ternary alloy. However, such cases would be rare, and usually the composition of such a complex alloy would be exactly defined. As regards alloys containing two or more metals in equal or nearly equal quantities, the committee suggest that the names of the metals should be placed in numerical order; but unless there is some distinguishing characteristic it would be liable to mislead, since the system would imply that the second name was that of the metal present in largest quantity. This difficulty might, however, be overcome by connecting the two metals with a sign of equality instead of a hyphen. For instance, a copper-zinc alloy of equal proportions could be designated as "copper = zinc," or if three metals were present in equal quantities, say, copper, lead, and zinc, it could be designated as "copper = lead = zinc." Although the committee so far deal only with "brass" and "bronze," these are the most widely used alloys in engineering work, and the adoption of their suggestions would do much to remedy the confusion at present existing through the careless use of these names. We hope, therefore, their efforts will be supported. With the general recognition of the principles proposed, the evolution of practical names is a matter for further consideration, and we shall await with interest the issue of the next report, in which this aspect of the question will be dealt with.

COMPARATIVE ECONOMICS OF TRAMWAYS AND RAILLESS ELECTRIC TRACTION.

In a paper on this subject read by Mr. T. G. Gribble, M.Inst.C.E., before the Institution of Civil Engineers, on March 24th, the author discussed the various economic features of the railless electric traction system, as compared with those of tramways, with a view to the definition of the sphere of usefulness which was open to the former. The initiation of the system in this country, in contrast with the general history of new forms of transportation, was due, not to Government aid or private enterprise, but to municipal tramway committees. It was pointed out that the Light Railways Act had failed to effect what was intended by it, and in contrast, attention was drawn to the immense and profitable development of light railways in Belgium. The necessity for the further utilisation of the highways was urged, because of the centralisation and congestion of population which had resulted from the development of the railway system. The distinctive economic features of tramways and railless electric traction were defined, and an analysis was made of the statistics of British municipal tramways, both as to cost of construction and working expenses. Railless electric traction was compared with the tramway as to carrying power, capital expenditure, and working costs, by means of generalisations deduced from the above statistics.

The author drew attention to the great variation in the cases cited of the cost of energy, greater than could be accounted for by the price of fuel. Cases were added of foreign tramways which operated with trailer cars. An illustrated description was given of tests made by the author of current consumption on an electric omnibus propelled by means of accumulators on London streets, also of tests made on a railless electric car at Bradford. The general conclusion arrived at was that it required no more current to carry the passenger by railless electric traction than it did by a tramway.

The following are the general conclusions arrived at: (1) That with a traffic density represented by a 2½ minute service the economy of construction and operation was still in favour of railless electric traction; as to cost of operation by about 7 per cent., and as to cost of construction by about 44 per cent. (2) That the economy increased inversely with the traffic density; so that with a time interval of 30 minutes, the economy of operation was about 36 per cent., and that of cost of construction about 70 per cent. Reference was made to the York tramways, the most recent case of a municipal tramway, in support of the argument that an even more important point than that of saving of expenditure was the possibility, by means of economic transportation, of serving the suburbs and the rural population. It was argued that the tramway at York, six miles in length, excellent though it was, did not serve all the suburbs, and that, by means of railless electric traction, for the same capital expenditure, 16 miles might have been constructed and operated; thus completely reaching the extreme suburbs, and incidentally raising the value of property in the vicinity of the city.

THE RUNNING OF GAS ENGINES AND GAS PRODUCERS.*

BY W. A. TOOKEY, M.I.M.E., M.I.A.E.

IN the present paper the author has considered it advisable to confine his attention to some of the more usual defects prevalent in gas engine operation that have come under his notice. A usual complaint in connection with those supplied with town gas is that an engine is alleged to work unsatisfactorily on account of "dirty gas," "bad gas," or "lack of pressure." Those responsible for making such allegations seem to be unaware of the obligations of gas companies to distribute gas of standard quality and purity, and of the continual observations taken by officials of various public authorities to prove that the standard is strictly adhered to. But accepting, for the sake of argument, that wide variations in gas quality do occur from day to day, it is difficult to account for any reasonable complaint on this score when it is remembered that one and the same engine can as readily deal with town gas of 500 B.Th.U. per cubic foot as with producer gas of only 130 B.Th.U. per cubic foot.

As with quality of gas, so with pressure. One and the same gas engine can work as comfortably with town gas at a pressure of 3in. of water column above atmospheric, as with suction producer gas with 8in. or 9in. of water below atmosphere. For these variations the attendant knows that in the one case he has to adjust his gas cock to be partially opened, and the air regulator wide open, while in the other he has to put the gas regulator wide open and the air baffle partially closed. By means of indicator diagrams, these adjustments can be readily effected, and, even when no indicator is available, it is a simple matter to obtain proper mixture proportions and efficient working.

When investigating complaints the author has found irregular running of gas engines on town gas to be partly, if not mainly, due to the gradual increase of "clearances" between valve gear rollers and cams, or blockage of exhaust connections. In one instance an engine had been gradually getting less and less powerful until the force of the impulses was barely sufficient to rotate the engine without load. The engine was a small one, and therefore had little margin for loss of power. Indicator diagrams showed that the exhaust back pressure line was extremely high, and upon disconnecting the exhaust pipe at the outlet of the "silencer," a crust of burnt oil forming a cake which almost completely blocked the outlet was found. When this was removed the engine ran satisfactorily. Blockage of exhaust pipes is not at all an infrequent experience. Many attendants carefully grind in the exhaust valve and think that this is the only thing that needs their attention. Copious lubrication—and very frequently the amount is needlessly excessive—involves some oil vapour passing and coagulating in the exhaust connections and in places where some constriction occurs, as in the outlet from an exhaust box or silencer, or between the interstices of the gravel with which some exhaust boxes are partially filled. Cases have occurred where it has become necessary to use a hammer and chisel to break up the solid mass of gravel and coagulated oil which has resulted from the accumulation of the latter through many years.

Engines in residential neighbourhoods are often fitted up with special devices to lessen the noise of the exhaust emission. In many instances a series of exhaust boxes are provided for this purpose. In one factory in London the author found as many as five boxes used for this purpose, arranged with double bends and straight connections alternately, as indicated in Fig. 1. These so restricted the escape that several horse-power was required to force the gases through the silencers, and a long vertical pipe to the roof of the building. The engine in question was required to operate at about its full power, and it was resolved, on the author's suggestion, to re-arrange the exhaust pipe by removing the series of boxes to the roof, leaving only the long vertical pipe to connect these with the engine cylinder. This had the desired effect. Those who plan exhaust piping rarely consider the effect of lessening the velocity of the exhaust gases close to the engine. The pressure at which the gases are first expelled from the cylinder at the point of release is from 30lbs. to 40lbs. per square inch, and the velocity due to such pressure should be taken advantage of, to overcome the resistance of the moving column of gases through the exhaust connections, any necessary throttling to obviate possible nuisance through the noise of emission at the final pressure being obtained by terminal silencers.

Another common defect of gas engine operation is due to the attendant failing to check over the valve settings from time to time, and especially after "overhauling." Apart from loss of power due to improper regulation of ignition devices, it may be safely alleged that diminution of power developed by a gas engine is frequently consequent upon irregular valve settings. In many cases the setscrew forming the point of contact between the valve lever and the exhaust valve spindle either receives no attention at all or else receives too much. If the former, the gradual wear that takes place involves contact taking place later and "coming away" earlier, consequently the exhaust valve is lifted from its seat later in the stroke, and comes again to its seat before the correct time. This diminishes the duration of the valve opening, and has a tendency to unduly bottle up exhaust gases within the cylinder, involving, not only the heating up of the fresh charge, but reducing the density of the latter, and therefore reacting upon the power of the engine. To maintain proper results the attendant should assure himself from time to time that the contact between the exhaust valve

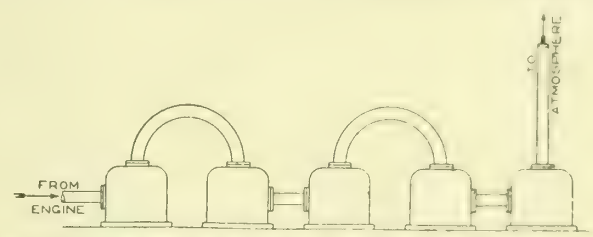


FIG. 1. ARRANGEMENT OF EXHAUST BOXES INVOLVING EXCESSIVE BACK PRESSURE WHEN PLACED CLOSE TO THE ENGINE.

lever roller and its cam, or between the setscrew and the end of the valve spindle, just "comes away" after the inner dead centre has been passed by the connecting rod.

The question has often been raised by attendants whether the lift of the exhaust valve is affected by valve setting. The answer is, Yes! The lift of the valve is primarily determined by the contour of the cam, and, secondarily, by the clearances. As the nose of the cam is worn the lift gradually lessens, but unless the wear is considerable, the working of the engine is not perceptibly affected. The variation of the valve settings on the other hand decides when the valve opens and closes, and excessive clearance diminishes the "lift." As a general rule, 5 per cent. either way of the correct position for the valve settings does not materially affect the working of the engine. In passing, it may be mentioned that loose motion through wear of valve fulcrum pins and their bearings is sometimes the cause of defective operation or loss of power.

The mixture valve setting is somewhat important, for, if this be "timed" for too short a period, the volume of mixture admitted is seriously curtailed. In horizontal, single-cylinder engines, the mixture valve, or main inlet valve, is given a lead of about 20° of the crank pin circle and a lag of the same amount. In vertical engines and others of the multi-cylinder type fed from the same induction pipe, the lead is frequently reduced, and sometimes is a minus quantity; the lag, however, is retained, as it is important that full advantage be taken of the inertia of the moving column of gases flowing towards the valve during charging, thus securing better filled cylinders than could be obtained with the valve closure taking place at or about the out-centre of the crank. For the latter would mean that the aperture through which the mixture must pass the valve would be practically nil during the final portion of the charging stroke, and would create such a resistance as would nullify the momentum of the mixture outside the cylinder. It is advisable, therefore, to check the mixture inlet valve settings from time to time to ensure the maintenance of

* Abstract of paper read before the Junior Institution of Engineers, March 16th, 1914.

sufficient lag. The opening side of the cam operating the valve gear is comparatively unimportant. It should, nevertheless, be definitely understood that too much lag is undesirable, as although the valve lift in its later stages is very slight, yet the advancing piston into the cylinder should be given no chance of pushing out any of the charge already admitted.

The effect of wear on contact points in producing shorter periods of valve operation is not so serious with either exhaust or inlet valves as upon ignition or timing valves fitted with "hot tube" devices. Grinding of the valves upon their seat tends to lengthen the valve spindle, and when ignition valve grinding is done with more zeal than discretion the contact of operating details will take place sooner, and continue for a longer period, thus resulting in later ignition and loss of power. On the other hand, substitution of one "timing valve and spindle combined" by another having a slightly different overall length—shorter, for example—will delay the time of contact and advance the time of release, again affecting the firing of the charge. Similarly, wear of the timing valve cam will involve shorter lift of the valve, while the wear of the lever roller increases the clearance between contacts and again affects the firing point. Any lost motion in the ignition mechanism is serious, and must be put right to secure reliable running under full loads. The proper timing of ignition is one of the most important details of gas engine operation. The author has found that a number of engines operate under conditions verging upon what is known as pre-ignition, mainly through the lack of adequate means for adjusting the time of firing to suit the particular strength of mixture with which the engine works. During recent years the author has conducted a series of tests upon engines working with town gas throughout the London area, and in each case the strength of mixture with which the engine was supplied has been particularly noted. Speaking generally, it may be said that it is of the utmost importance that, according to the strength of the mixture used, so the ignition timing must be suitably adjusted. Weak charges of the order of 35 B.Th.U. per cubic foot of mixture present in the total cylinder volume require the ignition timing to be advanced to a greater amount than when the normal or "rated" outputs demand mean pressures of 90lbs. to 96lbs. per square inch, with mixture strengths of 45 B.Th.U. To obtain best efficiency with some ignition valve settings, it has been found necessary to increase the mixture strengths to 50 B.Th.U. per cubic foot, or thereabouts, pointing to the fact that mixture strength and ignition timing go hand in hand. With other and earlier ignition settings it has been found impossible to use mixture strengths greater than, say, 40 B.Th.U. per cubic foot, because of the violent bumping that ensues. Mention may here be made of the "blowing by" that usually accompanies early firing. In not a few instances the amount of oil vapour proceeding from the mouth of the engine cylinder has been pointed out by the attendant as an indication of the necessity of a new liner and piston. Without saying that in every case the liner and piston were in good condition, it can be averred with truth that frequently the "blowing by" is simply the result of early ignition. The strong mixtures necessary to give impulses sufficiently powerful to deal with the load under which the engine was working, involved rapid inflammation of the combustible immediately upon the operation of the timing valve, so that flame propagation was proceeding whilst the piston was completing the compression stroke and the crank was passing its inner dead centre. Under such circumstances very high piston temperatures are reached, and it is not surprising that under these circumstances the lubricating oil should be converted into oil vapour and be ejected from the sides of the piston in clouds, which might reasonably be thought to be gas passing the piston and its rings. Upon one occasion the author was called to an engine that had been fitted with a new liner and piston, and respecting which it was found that the latter state of affairs was no better than the former. It had been suggested that the "blowing by" was explicable by the fact that the new rings had not properly bedded themselves in, and it was also suggested that the passing of the gas would be lessened as time went on. Such, however, was found not to be the case. In this instance it was proved that the "blowing by" was entirely obviated by the proper setting of the timing valve to suit the mixture strength used.

In connection with an installation in the neighbourhood of Manchester, the author investigated a complaint made with respect to two throttle-governed engines working on to one main shaft, from which three dynamos were driven, each electrically connected to a common bus-bar. It was found that, at irregular intervals during the day, one or other of the two engines, with puzzling impartiality, would suffer from a fit of pre-ignition, not serious in itself, but undoubtedly annoying, for it necessitated the dropping of the load for a few seconds until the engine affected had been able to clear itself, so to speak, by the introduction and expulsion of several consecutive charges of cold air only. Various expedients had already been tried, such as the removal of the exhaust box to the end of the connections, to obtain better scavenging by natural action of the inertia of the exhaust gases. Different settings of the valves had been made, new sparking plugs tried, and the suction gas plant, to which the engines were connected, was thoroughly overhauled and the water supply to the generator restricted, as it was thought possible that an undue percentage of hydrogen was present in the composition of the gas. None of these experiments were successful in preventing the recurrent attacks of pre-ignition, and finally the whole trouble was proved to be due to the unduly early setting of the electric ignition device. When the spark was retarded to the utmost limit provided by the quadrant and stop, by means of which the relative position of the magneto trip block was controlled, the point of firing was still much too early for the strength of the mixture used, and that this was the true cause was conclusively demonstrated by the satisfactory operation of both engines after the point of firing was altered.

The rapidity of flame propagation throughout the mixture in gas engine cylinders is greatly intensified by the temperature of the charges at the termination of the compression stroke. Naturally, the degree of compression for which the engine has been designed largely influences the temperature of the compressed charge, and occasionally questions are asked as to the most suitable compression pressure. It has been amply proved that engines with moderately high compression pressures give high thermal efficiencies, other things being equal. Mean pressures of the order of 90lbs. to 95lbs. per square inch can only be utilised in gas engine cylinders when intermission of "cut-out" or idle strokes occur, for with these pressures the internal temperatures resulting from combustion of the charges are the practical maximum that experience has taught to be safe. As long as the maximum temperature does not exceed the limit imposed by the practicable mean pressures already mentioned, the author's experience seems to indicate that compression pressures of 150lbs. or 160lbs. per square inch with town gas can be utilised, provided that adjustable electric ignition is fitted which gives facilitates for the retardation of the spark when full loads are being carried. On the other hand, not much is gained in the usual conditions of operation by carrying the compression pressure beyond 100lbs. or 120lbs. per square inch. Under test conditions, the thermal efficiencies with 160lbs. compression show to slight advantage, but, as will be seen from the chart, Fig. 2, the advantage is so slight that it is doubtful whether the greater risk of the occurrence of higher cylinder temperatures is worth while. This chart shows the actual efficiencies that have been obtained from a number of engines of great variety outputs under test conditions, as reported by various authorities during the last 30 years, and it will be evident that the comparatively slightly higher efficiency obtained by increasing the compression pressure from 120lbs. to 160lbs. is almost negligible.

Some qualification of this statement is, however, desirable in respect of the modern developments of gas engine practice, and particularly with reference to the improved methods of governing by the abandonment of "hit and miss" devices for control on the "graduated quantity" system. In

the latter the position of the throttle controlled by the governor reduces the volume of the mixture admitted, so that the cylinder is filled with a less dense mixture as the speed of the engine tends to increase. The variation of compression pressure as a direct consequence of this method of control renders it obligatory for the designer to provide for such maximum pressure with a full charge that, at the lighter loads, the reduced compression pressure will still be sufficient, not only to give fair economy, but also to maintain regular firing of the attenuated "light load" charges. Experience has shown that the maximum compression pressure of from 120lbs. to 150lbs. per square inch accords with good practice.

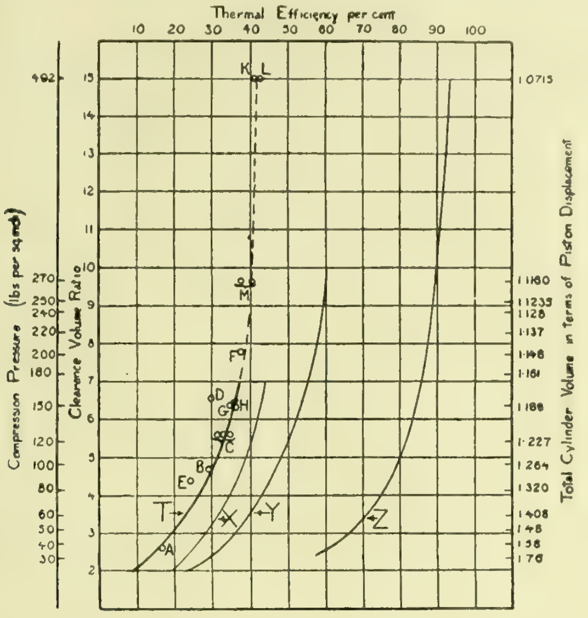


FIG. 2.

Z=Increasing efficiency with increasing compression pressure, due, by reason of reduction in clearance volume, to lesser total quantity of heat required to maintain equivalent mixture-strength.

Y=Air standard efficiencies on basis of constant specific heat (Inst. C.E. Committee, 1905).

X=Clerk's corrected efficiencies on basis of varying specific heat (Junior Inst. E., Canet Lecture, 1913).

T=Tookey's curve of practical efficiencies (Z × X=T).

The circles and dotted continuation of curve T show the actual efficiencies obtained by various experimenters during thirty years (1881 to 1911), as accompanying Table A, and their close agreement with Tookey's curve.

TABLE A.

Table of Tests from which were Obtained the Actual Efficiencies of Engines Plotted around Curve T.

Reference Letter.	Test by	Maker of Engine.	Date.	Size of Engine.
A	Slaby	Otto	1881	4·5 b.h.p.
B	Humphrey	Crossley	1900	360 b.h.p.
C	Inst. C.E.	National	1905	L, R, and X engines.
D	Stead	National	1911	750 b.h.p.
E	Clerk	Crossley	1894	12 b.h.p.
F	Burstall	Crossley	1904	50 b.h.p.
G	Atkinson	Crossley	1905	40 b.h.p.
H	Hopkinson	Crossley	1908	40 b.h.p.
K	Longridge	Diesel	1905	500 b.h.p.
L	Longridge	Diesel	1905	80 b.h.p.
M	Robinson	Ruston	1910	50 b.h.p.

(To be continued.)

Special Alloy Steels.—At a meeting of the Institution of Mechanical Engineers held on the 20th inst., at Storey's Gate, London, the president, Sir H. F. Donaldson, in the chair, Prof. J. O. Arnold, of Sheffield University, and Prof. A. A. Read, of Cardiff University College, contributed the result of their joint research upon the "Chemical and Mechanical Relations of Iron, Tungsten, and Carbon, and of Iron, Nickel, and Carbon."

BOOK REVIEWS.

Suspension Bridges, Arch Ribs, and Cantilevers. By William H. Burr, Professor of Civil Engineering, Columbia University. New York: John Wiley & Sons. London: Chapman & Hall. 9¼in. by 6¼in.; 418 pp. Price 19s. net.

From an engineering point of view America can no doubt be considered preeminent in bridge construction, and naturally its literature on the subject is extensive. It forms a prominent feature in many university curriculums and is expounded by many able men. Like the subject of mechanics in this country, however, nearly every teacher feels it incumbent upon him to write a book, with the result that it is difficult to single out particular authors for special praise, especially as the mechanical principles involved remain pretty much the same. There is, however, in bridge construction ample scope for variation in detail, and any author who seeks to work out particular examples can readily find ample material for a copious volume. The one under notice, as the author informs us, has been written primarily to meet his needs in the classroom, and it is from this point of view rather than that of the bridge constructor one must judge of the manner in which he has performed his task. It is certainly not lacking in detail as far as the mathematics are concerned, but however valuable this may be to students of a particular course, it inevitably takes up a great deal of space, and correspondingly restricts the breadth of treatment which other readers might prefer. We do not wish to imply that the book is lacking in thoroughness as regards the portions of the subject treated upon, and to many students the author's treatment may perhaps be preferable. We think, however, the value of the work would be enhanced if the index were more thorough. A volume of this size deserves more than an index covering 2½ pages especially when one considers that the contents occupies about three times the space. The price strikes us as being stiff, but the work emanates from America, where a higher standard of remuneration appears to attach to the work of engineering authors and where, if we may judge from the character of the printing paper used, books are also valued according to their weight.

* * *

Power and Power Transmission. By E. W. Kerr, Professor of Mechanical Engineering, Louisiana State University. New York: John Wiley & Sons; London: Chapman and Hall. 9¼in. by 6¼in.; 319 pp. Price 8s. 6d. net.

This is a pretentious-looking volume with very little in it, and may be summed up as a work on very elementary mechanics coupled with some simple general descriptions of boiler and engine details. It is unworthy to be regarded as a text-book, and if the engineering matter here incorporated may be taken as a measure of the standard of teaching which passes current in the State University of Louisiana then the standard is an elementary one. The matter here presented certainly does not in our opinion deserve the expenditure of 2lbs. 4ozs. of paper, and binding.

* * *

Working Drawings of Machinery. By Walter H. James and M. C. Mackenzie, Instructors in the Massachusetts Institute of Technology. New York: John Wiley & Sons; London: Chapman & Hall. 9¼in. by 6¼in.; 144 pp. Price 8s. 6d. net.

This volume, like the one just noticed, is a piece of pretentious bookmaking, and after glancing through its pages—we are amazed that it should be put forward as a text-book or endowed with the title appended to it. To call such elementary sketches as are given "working drawings of machinery" is an exaggeration. There are, it is true, four or five folding plates giving particulars of such details as the flange of a pipe, and one or two lathe chucks, but these might just as well have been given in the reading pages, and with the exception of these the remaining drawings are most elementary. We have no hesitation in saying that much better text-books on the subject of machine construction and mechanical drawing are available to English readers at one-fourth the price.

INTERNAL-COMBUSTION LOCOMOTIVE.

In locomotives of the type which are driven by internal-combustion engines it has been proposed to transmit the power to the driving wheels by means of hydraulic gears, thereby eliminating the disadvantages attendant on the use of toothed wheels or chains. The interposition of a hydraulic transmission enables the engine to be put in any position, and to alter with safety and rapidity the driving direction and speed of the locomotive without altering in the least the direction of rotation and number of revolutions of the engine.

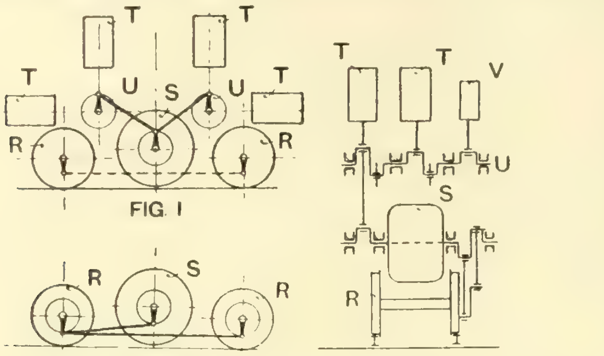


FIG. I FIG. 3. FIG 2

The accompanying illustrations show diagrammatically an arrangement of a locomotive, the invention of the Vulcan Works, Hamburg, in which the power of the engine is transmitted to the wheel axles by the interposition of a hydraulic gear of the Föttinger type. Fig. 1 is an end elevation, Fig. 2 is a front elevation, and Fig. 3 shows a special coupling of the hydraulic gearing with the driving wheels. The arrangement illustrated shows shafts parallel to the axles of the locomotive, but these shafts can be at right angles to the latter. The number, arrangement, and coupling of the cylinders can also be varied as desired. The Föttinger hydraulic gearing S is arranged between the coupled driving wheels R and is coupled with the latter, as shown in Fig. 3. The cylinders T, one set of which may be vertical and another set horizontal, operate as shown, on both crank shafts U, which are parallel to the driving axles. The masses of the driving parts of each of the vertical and horizontal engine sets, which both act upon one engine shaft, are balanced with regard to each other, whilst the masses of the driving parts of all the internal-combustion engines acting upon the driving axle are so arranged and dimensioned that they are wholly balanced. The internal-combustion engines can therefore work either on a single shaft or directly on the hydrodynamic gearing. The two shafts U are either separately connected with the hydrodynamic gearing by means of angularly arranged connecting rods (Fig. 1) or both coupled and one of them connected to the gearing. The cooling and air pump cylinders V may be arranged on the common gear shaft and may be driven through the main internal-combustion engine as illustrated in Fig. 2. The cooling and air pump cylinders may, however, be driven from a special shaft other than the driving shaft of the main internal-combustion engine, the motor and shaft for this purpose being mounted at a suitable place in the locomotive. The engine cylinders may be arranged in several different ways. For instance, several sets of internal-combustion engines, each with its Föttinger gear, can be arranged one behind the other. The variation of speed and direction of a locomotive embodying the present invention should always be effected by means of the hydraulic gearing. But should certain working conditions cause it to appear advantageous the variation can be effected direct from the engine, or from the combined engine and hydraulic gearing, by reversibly constructing the engine and employing the hydraulic gearing to solely regulate the driving speed.

BRONZE.*

BY JOHN DEWRANCE.

The dictionary meaning of the word "bronze" is a compound or alloy of from 2 to 20 parts of copper to 1 of tin, to which other metallic substances are sometimes added, especially zinc. In times past, the gradually increasing additions of zinc and lead discredited the name of bronze. In the manufacture of guns it was found that the best results were obtained by an alloy of 9 parts of copper and 1 part of tin. This became the standard material for the manufacture of guns for many years. To distinguish this alloy from the inferior mixtures that had previously been supplied under the name of bronze, the description gun-metal was introduced. As time went on the new name gun-metal was no more respected than the old one of bronze, and at the present time any alloy that does not come under the description of pot metal or brass is called gun-metal. As guns are now universally made of steel, it seems desirable to return to the dictionary description and to call all alloys mainly composed of copper and tin "bronze."

To the previously-mentioned alloy of 90 per cent. copper and 10 per cent. tin, it is very largely the practice to add 2 per cent. of zinc, making 88 per cent. copper, 10 per cent. tin, and 2 per cent. zinc. When tested at atmospheric temperature this alloy gives very excellent results. As a great deal of bronze is used at the temperature of high-pressure steam it becomes important to investigate its behaviour at temperatures that correspond.

The tests, the results of which are given in Figs. 1 to 4, were conducted for the author by Mr. R. H. Harry Stanger. The heating apparatus was an air-tight tube boiler heated

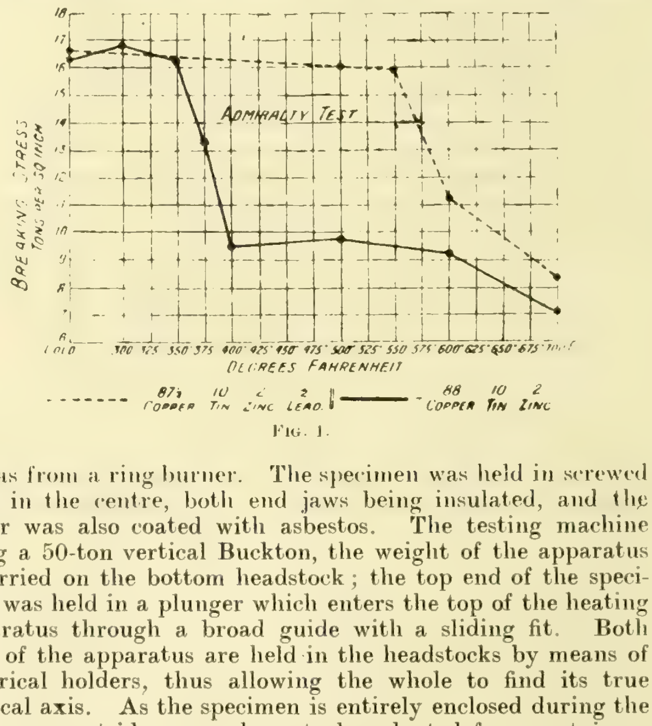


FIG. 1.

by gas from a ring burner. The specimen was held in screwed jaws in the centre, both end jaws being insulated, and the boiler was also coated with asbestos. The testing machine being a 50-ton vertical Buckton, the weight of the apparatus is carried on the bottom headstock; the top end of the specimen was held in a plunger which enters the top of the heating apparatus through a broad guide with a sliding fit. Both ends of the apparatus are held in the headstocks by means of spherical holders, thus allowing the whole to find its true vertical axis. As the specimen is entirely enclosed during the test, some outside means have to be adopted for ascertaining the yield point, if any; the two ends of the heating apparatus were connected to a Wickstead hydrographic recorder, taking the base line with the beam floating immediately before applying the load after the specimen has attained the necessary temperature.

An experimental specimen was drilled with holes in different positions along the parallel length, and the bulb of a thermometer was inserted in the various positions. This thermometer was found to agree very closely with another thermometer that recorded the temperature in the air chamber, and it was therefore inferred that the readings of the thermometer in the air chamber gave correct readings of the temperature of the specimen. The percentages of elongation were given by the Wickstead recorder, and are stated throughout as the percentage on 2in. The copper employed

* Paper read before the Institute of Metals, March 18th, 1914.

in these tests was that which is known on the market as "Best Selected," which has an average analysis as follows:

	Per cent.
Copper	99·55
Nickel	0·01
Arsenic	0·026
Lead	0·08
Bismuth	0·004

The tin and zinc were the best commercial quality. In the first tests made 88 parts of copper were melted in a new crucible, 2 of zinc were added as soon as the copper was melted and allowed a short time to flux the metal, 10 of tin were then added, the whole mass stirred, and the test pieces poured at as near the same heat as could be judged by a careful moulder. The black line on Fig. 1 shows that at atmospheric temperature the 88 copper, 10 tin, and 2 zinc alloy has a maximum stress of 16·35 tons per square inch, and the black line on diagram, Fig. 2, shows an elongation of 11 per cent. on 2in. At 400° Fah. it has a maximum stress of 9·5 tons, and an elongation of only 1 per cent. At 700° it has a maximum stress of 7 tons, and an elongation of 0·25 per cent.

The first series of tests undertaken was that between 400° and 700° Fah., and the results were so unexpected that it was thought advisable to re-test some of the broken samples in the cold state, to ascertain if the fault was in the casting of the test pieces. For this purpose samples which had failed at 400° Fah. and 500° Fah. were turned down and suitably

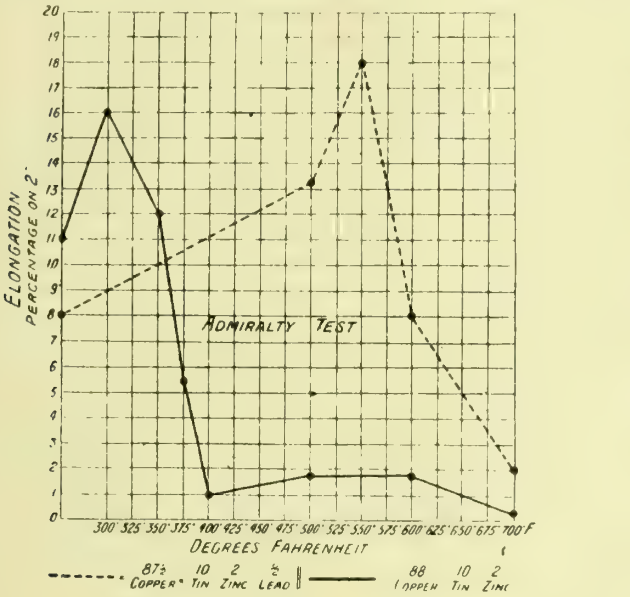


FIG. 2.

mounted, and when re-tested at atmospheric temperature gave a breaking stress near 18 tons per square inch. Further samples in this same mixture were then prepared and tested at temperatures between atmospheric and 400° Fah., and the results, embodied on the diagram Fig. 1, show very clearly that the metal begins to lose its strength above 350° Fah. Prof. Huntington, in a paper* read before the Institute in 1912, gives among other alloys particulars of an alloy of copper 97·673 and tin 2·408 tested cold, and at temperatures up to 870° Fah. Having regard to the small proportion of tin, these results are consistent with the results given above.

In the next tests made 87½ parts of copper were melted in a new crucible, 2 of zinc were added as soon as the copper was melted, and allowed a short time to flux the metal; 10 of tin and ½ of lead were then added together, and the whole mass stirred. It will be observed that the only difference between this and the previous experiments is the addition of ½ per cent. of lead at the expense of the copper. The dotted line in Fig. 1 shows that at the atmospheric temperature the maximum stress is 16·5 tons per square inch, and the dotted line on Fig. 2 the elongation 8 per cent. At 550° Fah. it has a maximum stress of 15·8 tons, and an elongation of 18 per cent. At 700° it has a maximum stress of 8·25 tons, and an elongation of 2 per cent. The breaking stress of 11·25 tons per square inch at 600° Fah. is an average. No actual sample broke at this stress. It was found that some samples tested at this temperature gave results in the region of 16 tons per square inch, and others 7 tons per square inch. From this it may be concluded that 600° is the critical temperature of this alloy.

In a paper read before the International Association for Testing Materials at the seventh Congress in New York, 1912, by J. M. Bregowsky and L. W. Spring, of the Laboratory of the Crane Company, Chicago, the results are given of tests among others of a material called U.S. Navy Gun Bronze G, which has a composition of 87·6 per cent. copper, 10·4 per cent. tin, 1·31 per cent. zinc, 0·39 per cent. lead—it is also stated to contain 0·11 per cent. iron; but it is probable that the iron content given is due to using a file for preparing the sample for analysis, as such an alloy ought not to contain

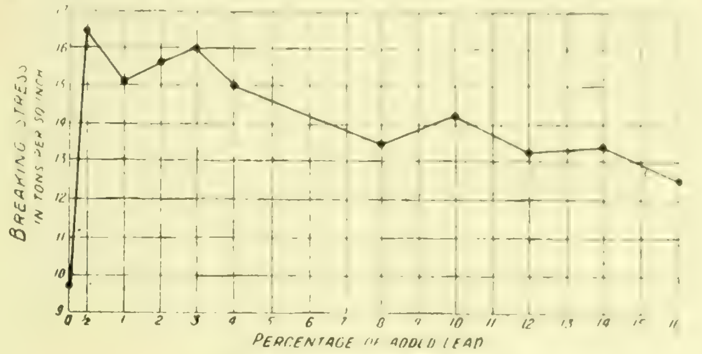


FIG. 3. TESTED AT 500° FAH.

such a proportion of iron. The chart of the test of this metal at first sight appears inconsistent with the results given in this paper; but this is due to the fact that the tests made were not sufficiently numerous. The first test appears to be at about 80° Fah., and gives a maximum stress of 15 tons, and elongation of 9 per cent.; the second test is at 300° Fah., and gives a slightly increased maximum stress of 16½ tons, and elongation of 9·5 per cent. The next test is at 450° Fah., and gives a maximum stress of 14·75 tons, and elongation of 8 per cent. There is not another test until 600° Fah., at which temperature the maximum stress is given as 10 tons, and the elongation as 4 per cent. As previously mentioned, 600° Fah. is the critical point, and it is unfortunate that there is such a wide gap of temperature between this test and the previous ones, as otherwise the results obtained would have been more consistent with the results given in this paper, and might have given information as to

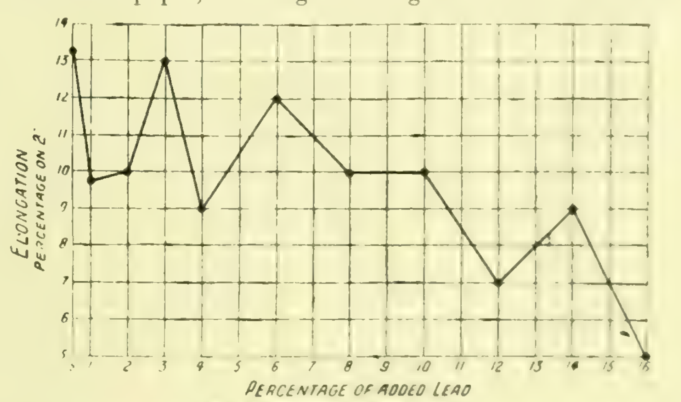


FIG. 4. TESTED AT 500° FAH.

the slight difference due to that particular composition of alloy tested.

If it is accepted that ½ per cent. of lead raises the maximum stress at 500° Fah. from 9·75 tons to 16·5 tons, that proportion of lead becomes an essential ingredient in bronze, that is, subjected to temperatures above 350° Fah. It also becomes necessary to enquire whether any further advantage can be gained by adding a larger proportion of lead. Figs. 3 and 4 show that this is not the case; but it is surprising that with so large a proportion as 16 per cent. of lead the maximum stress at 500° Fah. is 12½ tons, as against 9·5 tons without any lead. In making these experiments the lead was added at the expense of the copper. So the last result would be 72 per cent. copper, 10 per cent. tin, 2 per cent. zinc, 16 per cent. lead.

* "Journal of the Institute of Metals," 1912, No. 2, Vol. VIII., p. 131.

In making the foregoing experiments the question arose as to whether any of the results were due to the absorption of oxygen from the atmosphere by the alloy when in a molten condition. It is difficult to determine the content of oxygen in bronze, so the following experiments were conducted with best selected copper: —

Experiment No. I.—A new 100lbs. plumbago crucible was taken. As soon as the copper was sufficiently hot an ingot was cast, and the rest of the metal was returned to the fire for an hour, when a second ingot was cast, and the same thing repeated for the third ingot. There were thus three ingots cast from the same crucible at intervals of one hour. On analysis the oxygen contents of the three were as follows: —

	Oxygen per cent.	Cuprous Oxide per cent.
No. 1	0·032	0·285
No. 2	0·272	2·499
No. 3	0·404	3·605

Experiment No. II.—Two new plumbago crucibles containing 100lbs. of best selected copper were taken, and ¼lb. of 10 per cent. phosphor-copper was added to one, and 0·6oz. aluminium to the other, as deoxidisers. The copper was covered with glass, so that when molten no air could come in contact with it; and three ingots were cast at intervals of one hour, as in the former experiment, the glass being left on during the casting.

Oxygen Contents on Analysis.

		Oxygen per cent.			Oxygen per cent
Aluminium as deoxidiser	No. 1	0·084	Phosphorus as deoxidiser	No. 1..	0·036
	No. 2..	0·080		No. 2..	0·036
	No. 3..	0·092		No. 3..	0·036

Both sets of results show that if the metal is kept from contact with the air when molten no oxygen is picked up; and if this precaution is not taken each melting will result in an increase in the content of oxygen, and this conclusion was accepted and acted upon when making the following experiments. The products were not analysed for oxygen on account of the previously mentioned difficulty of such analysis.

Experiment No. III.—One new plumbago crucible containing 100lbs. of 87½ per cent. copper, 10 per cent. tin, 2 per cent. zinc, and ½ per cent. lead was covered with glass to exclude the air and melted; another exactly similar charge was allowed ample opportunity to pick up oxygen by being repeatedly skimmed and left standing in the air after being taken from the fire. Test-pieces, and a heavy flange casting with a light and thin nipple on each side, were cast from each crucible. The flange castings were broken and examined very carefully, and both appeared as sound as it is possible to get a casting. The test-pieces gave the following results when tested cold and under heat: —

	Temperature	Maximum Load in Tons per square inch.	Extension on 2 inches. per cent.
First charge covered with glass to exclude oxygen ..	Cold	15·17	9·0
	At 500° F.	13·73	10·5
Second charge uncovered to absorb oxygen	Cold	16·55	12·5
	At 500 F.	15·15	14·0

Experiment No. IV.—To complete the above results Experiment No. IV. was made, which consisted in casting a similar flange and test-pieces in "twice run" metal. The flange casting again proved sound, and the test-pieces gave the following results: —

	Temperature	Maximum Load in tons per square inch.	Extension on 2 inches, per cent.
Metal twice run without any precaution to prevent absorption of oxygen......	Cold	15·19	8
	At 500° F.	16·15	14

The foregoing experiments point to the conclusion that in an alloy of 87½ per cent. copper, 10 per cent. tin, 2 per cent. zinc, and ½ per cent. lead, no benefit results from the deoxidation of the metal, or in taking special precautions to prevent the metal absorbing oxygen. There is another feature of considerable interest in these alloys. When the alloy that is free from lead is turned in the lathe the turnings have a considerable curl upon them. The addition of ½ per cent. of lead materially reduces the length of the turnings. It would naturally be supposed that this feature is due to the fact that without the lead the alloy has an elongation of 11 per cent. on two inches, and with the addition of the lead the elongation is reduced to 8 per cent., and that the turnings break off more readily for this reason. The same test-pieces from which the turnings were made when cold were then heated and turned at 550° Fah., when it was found that the alloy without the lead still presented the same curly appearance, and the turnings from the alloy containing the ½ per cent. of lead were very little longer than the turnings produced at the cold.

The elongation of the alloy containing ½ per cent. of lead was at 550° Fah., 18 per cent. on two inches; whereas the elongation of the alloy without the lead fell at this temperature below 2 per cent.

As lead has such a marked effect on bronze, enabling it to be used without loss of strength up to 550° Fah., it seems reasonable to expect that some other metal might be added that would enable the bronze to withstand even higher temperatures. With this object in view 87·25 copper was melted in a new crucible, and 0·25 of silver was added when the copper was melted, and the whole mass stirred. Ten per cent. of tin and 2 per cent. of zinc, and ½ per cent. of lead were then added and again stirred. Two test-pieces were prepared and tested at 700° Fah. One test-piece gave a maximum load of 8·11 tons, the other 8·75 tons. The extension in neither case exceeded 0·5 per cent. on two inches. The maximum load is practically the same as without the silver, and the extension not so good. Nickel is not very promising, as in small proportions it seems invariably to liberate some occluded gas on cooling, and produces very porous castings. Aluminium is objectionable, because in even small proportions it seems to add materially to the amount of the contraction of the casting on cooling. Iron is strongly objected to in fine bronzes, as it combines with the tin and separates out into hard masses in the casting.

The subject seems to call for further research, as it is possible that small proportions of some of the rarer metals may have a beneficial effect. With the present use of superheated steam it is very desirable that a bronze should, if possible, be produced that can be used with safety at 700° Fah.

South Staffordshire Iron and Steel Institute.—At a meeting of this Institute, held at Dudley on Saturday last, Mr. J. Ernst Fletcher read a paper entitled "The 4·3 per cent. Carbon Eutectic (White Iron) and its Relationship to Iron and Steel Structure and Manufacture." He said it was recognised by all students of iron and steel that the greatest practical importance attached to a comprehensive and clear knowledge of the behaviour of carbon, iron, silicon, manganese, sulphur, and phosphorus in their association in alloys used in the various iron and steel-making processes. The complexity of the relationships between iron and the various metals and metalloids had not deterred metallurgists from attacking the difficulties, and there was to-day a mass of invaluable information as the result of numerous researches. In the main these researches had trended in four directions—the action of carbon on iron, the results of temperature changes in iron and carbon iron alloys, the action of other metals and metalloids on irons, the action of other metals and metalloids on carbon alloys. Naturally the research work done had been in connection with the influence of gases, metals, and varying temperature and heat treatment on pure iron or carbon irons. The results, though invaluable, often confused the practical issue, and his object in that paper was to look at the iron carbon problem from the point of view of that white iron-carbon alloy containing 4·3 per cent. of carbon, which might be called the basis of all present iron and steel-making processes excepting direct methods from the ore.

SCHMIDT'S CONSTANT-PRESSURE INTERNAL-COMBUSTION ENGINE.

HITHERTO it has been usual to regulate constant-pressure internal-combustion engines by adding to the constant weight of air corresponding to the cylinder volume a greater or less weight of fuel, according to the load. Combustion therefore takes place with varying quantities of excess air, so that widely different temperatures of combustion (about 1,000° C. difference between normal load and no-load) are produced in spite of equally high compression pressures and equally high

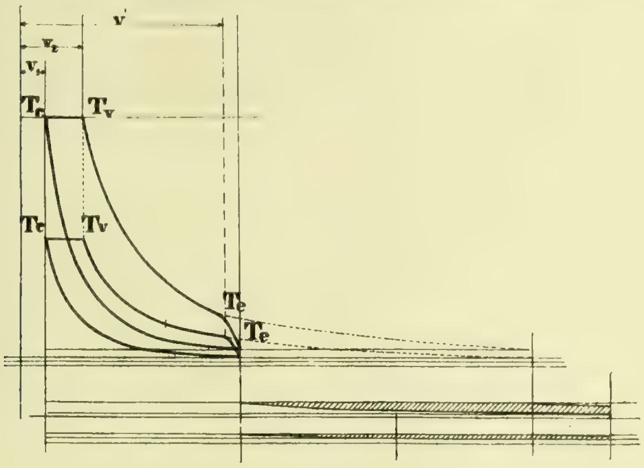


FIG. 1.

compression temperatures, while in addition the temperature of the exhaust gases may vary through a range of 300° C. and more. This variable exhaust temperature is specially disadvantageous in the case of constant-pressure engines, which work with combustion air subjected to a preliminary compression (of two to four atmospheres absolute or more for normal loads), and in which the exhaust is used in a hot-air engine. Thus it is well known that the output of a hot-air engine is mainly dependent on the difference in temperature of the working medium before and after expansion, and if this difference sinks below a certain amount, there is sometimes not sufficient power available to overcome the internal resistance of the engine itself.

In constant-pressure engines with pre-compression of the combustion air, according to present practice the temperature of the exhaust gases from the constant-pressure cylinder is so chosen with a view to economical working that at the highest load at which it is desired to work the energy available in the exhaust gases is, with a small margin for contingencies, exactly equal to the output desired from the hot-air engine. In such a case, if the load on the constant-pressure engine is diminished, it soon happens that the energy available in the exhaust gases which depends on their temperature, volume, and pressure becomes too small for the predetermined output of the hot-air engine. If, on the other hand, the energy available in the exhaust gases is chosen so that the hot-air engine performs the specified amount of work at normal loads of the constant-pressure engine, on working with an overload the exhaust temperature of the constant-pressure engine may be so high that in the case of reciprocating engines the piston corrodes, and in the case of turbines the blades become red hot.

To overcome these difficulties, the arrangement illustrated has been designed and patented by Dr. Wilhelm Schmidt, of 2, Rolandstrasse, Cassel-Wilhelmshöhe, Germany. It consists in a constant-pressure engine and a hot-air engine, in which the regulation is effected in such a manner that the hot-air engine, in spite of varying loads on the constant-pressure engine, is steadily supplied with exhaust gases of an approximately constant temperature. Not only is the supply of fuel varied, but the weight of air supplied to the working cylinder of the combustion engine proper is also varied in the same proportion. The variation of the weight of air is obtained by varying the pressure of the pre-compressed combustion air. At the same time the temperature of the pre-compressed air, which otherwise would vary according to the degree of the pre-compression, is maintained approximately constant by a preliminary cooling or warming of the air after pre-compression. The temperature at the end of the compression will then also be constant since, the ratio of compression in the combustion engine proper being the same at all loads, the temperature rise due to the compression likewise remains invariable. Any small difference which may result from the influence of the cooling jacket can be provided for during the preliminary cooling or warming of the pre-compressed air. The volume at the end of the compression also is constant for it is equal to the invariable volume of the compression space (clearance) of the cylinder. The pressure at the end of the compression varies according to the degree of the pre-compression; for instance, at half-load the final pressure is only half as high as at full load. The temperature rise and the increase of volume during combustion are equal at all loads, since the proportion between the quantity of fuel and the quantity of air is constant. Thus, finally, the temperature and volume at the end of combustion are the same at all loads, while the ratio of expansion and the temperature at the end of the expansion, *i.e.*, the exhaust temperature, are also invariable. The engine works with a constant cut-off, in contradistinction to the known Diesel engines, in which the degree of cut-off decreases with the load.

Referring to the illustrations, Fig. 1 shows a diagram of the engine working at different loads, the larger diagram corresponding to full load and the smaller to half-load (the admission periods and also the volumes and temperatures of the exhaust gases are the same in both cases), and Fig. 2 a diagrammatic sectional view of the engine. The combustion cylinder is shown at A, the hot-air engine at B, and the compressor for pre-compressing the combustion air at C. The combustion engine works on the four-stroke cycle, while the hot-air engine works on the two-stroke cycle. Between the two engines a receiver D is arranged for the exhaust gases from the combustion cylinder, while between the compressor and the combustion engine a receiver E is situated. In the outlet of the latter a throttle valve F is arranged, by help of which a higher pressure than is necessary for normal working can be maintained in the receiver. This is desirable in order to be able to follow the variations of load more rapidly. The course of the exhaust gases and the combustion air is shown by arrows. The decreasing weight of combustion air with decreasing output in constant-pressure engines reduces the work of pre-compression, the energy available in the exhaust gases likewise decreasing. Nevertheless, in contrast

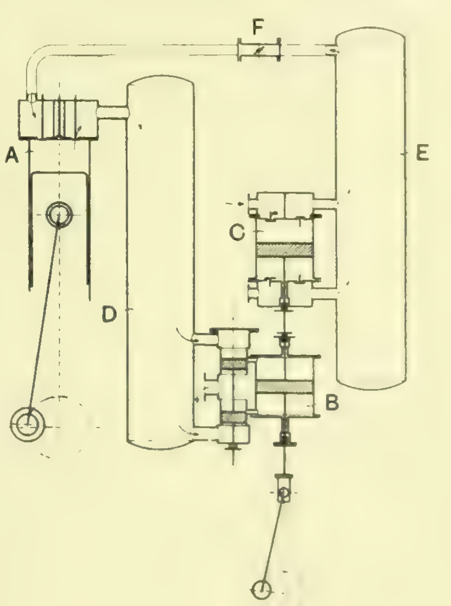


FIG. 2.

to installations governed according to known systems, the energy in the exhaust gases always remains greater than the work required for pre-compression. The distribution of work between the constant-pressure and the hot-air engines is chosen in such a manner that the constant-pressure engine performs the whole useful work, because it works with considerably more economy than the hot-air engine. If the hot-air engine is only used for the work of pre-compression, it is

preferable to make it mechanically independent of the constant-pressure engine itself. By using two mechanically independent engines, no restrictions are imposed by the revolutions per minute of the constant-pressure engine, and the hot-air engine can then be constructed as a turbine, as is advisable with large plants. Regulation of the pre-compression pressure is effected by altering the output of the compressor by aid of one of the known methods; for example, in a piston compressor, by holding open the suction valve during a part of the piston stroke.

In addition to the advantages above described in relation to the hot-air engine, the efficiency of the combustion itself is also improved by means of the new method of regulation. As a result of the equal work of compression at all loads, constant-pressure engines as at present known have a very low mechanical efficiency at light loads. In the engine under notice, since the initial pressure of the combustion air is reduced at light loads, the work of compression in the constant-pressure cylinder is reduced in the same degree, so that for all loads the mechanical efficiency remains substantially constant. The pre-compression plant may also be utilised for the production of the injection air. The weight of injection air required depends on the quantity of fuel, while the pressure of the injection air depends on the combustion pressure. Both alter in common and in the same sense with alteration of the initial pressure. It is therefore advantageous to take the air to be compressed for injection from the pre-compressed combustion air. The injection air compressor can be made smaller in view of the pre-compression. The arrangement is equally applicable to either two-stroke or four-stroke engines.

INFLAMMABILITY OF OIL WHEN SPRAYED ON HOT EXHAUST PIPES.

THE Board of Trade enquiry into the loss of the West Highland passenger motor boat "Scout," which caught fire in Loch Leven, in August last, and became a total wreck, was resumed on the 19th inst. At the previous meeting the Court adjourned in order that experiments might be carried out as to the inflammability of the oil in the bilges of the vessel when sprayed on a red-hot exhaust pipe by the flywheel of the engines. Mr. James Cormack, Board of Trade surveyor, reported that for the purpose of the experiments a model flywheel of the same diameter as those fitted to the engines of the "Scout" had been constructed, together with a trough measuring 4ft. by 1ft. to represent the bilge of the vessel, and an erection on which to place in relatively the same position a pipe of the same size as the exhaust pipes of the "Scout." The apparatus was fitted up to ascertain whether it would be possible for the flywheel on the port engine to throw the contents of the bilge on to the pipe if the liquid was brought into contact with the rim of the wheel when it was rotating at 450 revs. per minute. It was found that that was quite possible. Experiments were then conducted with a view to ascertaining whether pure lubricating oil floating on the surface of the bilge water would, when thrown on the heated pipe, ignite spontaneously, and also whether a mixture of lubricating and paraffin oils would do so under the same circumstances. With regard to the lubricating oil he had to state that when this was sprayed on to the hot pipe the oil vaporised in dense smoke which did not ignite unless a naked flame was passed through it. On reheating the pipe a quantity of finely-shredded cotton waste was thrown upon it. This burned immediately, leaving some glowing points on the pipe, and it was found that lubricating oil would then ignite, though not very readily, when sprayed on the pipe by means of the wheel. About a gallon of paraffin was poured into the trough, and on starting the wheel and stirring the contents of the trough so as to make them come into contact with the revolving wheel and be sprayed on to the pipe the mixture at once burst into flame. Mr. Cormack gave evidence with regard to further experiments, and stated that the general conclusion arrived at was that it was quite possible the fire might have orignated in the way described, if the bilges were sufficiently flooded to bring the oil floating on the surface into contact with the flywheel. That, however, would imply an abnormal amount of water in the bilges.

A COMBUSTION CHART FOR COAL AND OIL FUELS; AND A CHECK ON FLUE, EXHAUST, AND PRODUCER GAS ANALYSES.*

BY PROF. J. D. CORMACK, D.SC.

THE object of this note is to describe a combustion chart which gives a simple and rapid means of checking flue and exhaust and producer gas analyses, so as to ascertain whether a given gas analysis is consistent with the combustion of a given coal or oil fuel; and the chart gives also the air appropriated for the combustion, and the excess air used. The composition of the gases is ascertained as a volumetric analysis, and it is unnecessary to reduce this to a weight analysis. Let the fuel, as burned, contain per pound: C_1 lb. carbon, H_1 lb. hydrogen, and O lb. oxygen, and let the volumetric analysis of the gases be:—

Carbon dioxide ..	CO_2, x
Carbon monoxide	CO, y
Oxygen	O, z
Nitrogen ..	N, n
Total ..	1

Any sulphur in the fuel is usually very small, requires little oxidation, and does not appear in the gas analysis. The nitrogen in the fuel may also be neglected, as its weight is very small compared with the total weight of the gases. Following the usual assumption, the available hydrogen per pound of fuel as burned is $H_1 - \frac{O}{8}$, and the available hydrogen per pound of carbon burned is $\frac{H_1 - \frac{O}{8}}{C_1}$ or H^1.

Take the composition of the atmosphere as: By volume, oxygen 21 per cent; nitrogen 79 per cent. By weight, oxygen 23·2 per cent.; nitrogen 76·8 per cent., the nitrogen being understood to include the inert gases.

1lb. carbon requires, for combustion to $CO_2 \frac{32}{12}$ *i.e.*, $\frac{8}{3}$lb. oxygen,

and for combustion to CO $\frac{16}{12}$ *i.e.*, $\frac{4}{3}$lb. oxygen.

Therefore the air required for the combustion of 1lb. carbon to CO_2 is $\frac{8}{3} \times \frac{100}{23 \cdot 2}$, *i.e.*, 11·5lbs.; and for combustion to CO, 5·75lbs.

1lb. hydrogen requires for combustion to H_2O, $\frac{16}{2}$, *i.e.*, 8lbs. oxygen, and the air required is, therefore, $8 \times \frac{100}{23 \cdot 2}$, *i.e.*, 34·5lbs.

In dealing with the combustion of carbon, two facts are useful: (1) When carbon combines with oxygen to form CO_2, the volume of the CO_2 produced is equal to the volume of the oxygen used. (In all cases volumes are compared at the same temperature and pressure.) When, however, the carbon forms CO, the volume of CO produced is twice the volume of the oxygen used. The following statement can, therefore, be made at once: The ratio of the volume (or weight) of unused or excess air (or oxygen) to the volume (or weight) of the air (or oxygen) required for the combustion of carbon to $CO_2 = \frac{z}{x}$. (2) Equal volumes of CO_2, CO, and CH_4 contain the same weight of carbon. Hence it follows that if, of the total carbon C_1 burned, $C_1 (1 - S)$ is burned to CO_2, and C_1Sis burned to CO—

$$\frac{1 - S}{S} = \frac{x}{y}, \text{ or } 1 - S = \frac{x}{x + y} \text{ and } S = \frac{y}{x + y} \quad . \quad (1)$$

Consider the combustion of 1lb. carbon having H^1 available hydrogen. Let S lbs. be burned to CO, and $1 - S$ to CO_2, and let there be m lbs. excess air. The result of the combustion can be shown in tabular form. Take the volume of 1lb. oxygen as V. When a volume V of oxygen is taken from the atmosphere, the corresponding volume of nitrogen is $\frac{79}{21}$V, or, say, rV.

* Abstract of paper read before the Institution of Engineers and Shipbuilders in Scotland, March 17th, 1914.

For the combustion of	Vol. of oxygen required.	Vol. of products.	Vol. of nitrogen corresponding
(1 − S) lb. carbon to CO_2	$(1-S)\times\frac{8}{3}V$	$(1-S)\frac{8}{3}V$	$(1-S)\frac{8}{3}Vr$
S lb. carbon to CO	$S\times\frac{4}{3}V$	$2S\times\frac{4}{3}V$	$S\times\frac{4}{3}Vr$
H^1 lb. hydrogen to H_2O...	$H^1\times 8V$	*	$H^1\times 8Vr$
Add m lbs. excess air containing		$\cdot 232mV$ of oxygen.	and $\cdot 232mV\times r$ of nitrogen.

* No water appears in the gas analysis.

The resulting gas analysis will be (s being the sum of the items in the two right-hand columns):

$$CO_2,\ i.e.,\ x=\frac{(1-S)\frac{8}{3}V}{s}\qquad\therefore(1-S)\frac{8}{3}V=xs\quad.\quad(2)$$

$$CO,\ i.e.,\ y=\frac{S\times\frac{8}{3}V}{s}\qquad\therefore S\times\frac{8}{3}V=ys\quad.\quad(3)$$

$$O,\ i.e.,\ z=\frac{\cdot 232mV}{s}\qquad\therefore\cdot 232mV=zs\quad.\quad(4)$$

$$N,\ i.e.,\ n=r\frac{(1-S)\frac{8}{3}V+S\times\frac{4}{3}V+H^1\times 8V+\cdot 232mV}{s}\qquad(5)$$

Now from (2) and (3) adding, $\frac{8}{3}V=(x+y)s$ (6), and substituting from (2), (3), (4), and (6) in (5), we have

$$n=r\left\{x+\frac{y}{2}+z+8H^1\times\frac{3}{8}(x+y)\right\}$$

$$\text{and } x+y+z+n=1$$

$$\therefore n=r\left\{1-\frac{y}{2}-n+3H^1(x+y)\right\}$$

$$\text{also }\frac{r}{1+r}=\frac{\frac{\cdot 79}{\cdot 21}}{1+\frac{\cdot 79}{\cdot 21}}=\cdot 79$$

$$\therefore n=\cdot 79\left\{1-\frac{y}{2}+3H^1(x+y)\right\}$$

$$\text{or } n=\cdot 79\left\{1+3H^1\frac{x+y}{1-\frac{y}{2}}\right\}\left(1-\frac{y}{2}\right).\quad.\quad.\quad(7)$$

When, therefore, the value of H^1 and the amounts of CO_2 and CO in the flue gases are known, the amount of nitrogen can be found, and the oxygen got by difference, and thus a check on the analysis is obtained. The equation shows that if the CO_2 and CO are accurately ascertained, and if H^1 is known, the oxygen and nitrogen can be obtained by a simple calculation. Take as an example the combustion of a coal of analysis: Carbon, 81 per cent.; hydrogen, 4·5 per cent.; oxygen, 6·4 per cent.; other matters, 8·1 per cent. The ash per pound coal burned was ·06lb., and it contained 30 per cent. of C.

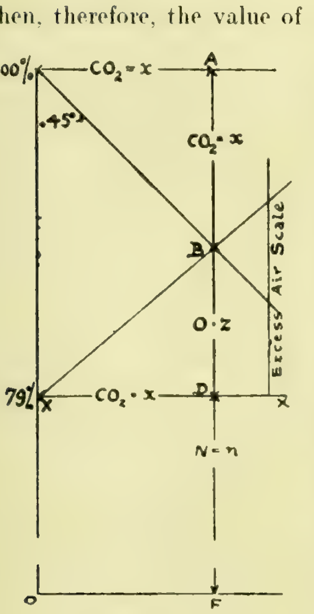


FIG. 1.

Per pound fuel C burned = ·81 − ·018 = ·792lb.

If any hydrogen was in ashes owing to unburned coal, a correction could, if necessary, be made, but it would be extremely small.

$$H^1=\frac{\cdot 045-\frac{\cdot 064}{8}}{\cdot 792}=\frac{\cdot 037}{\cdot 792}=\cdot 0467$$

The amounts of CO_2 and CO found in the gases were ·110 and ·012 by volume.

$$\therefore\text{ from (7) } n=\cdot 79\left\{1-\frac{\cdot 012}{2}+3\times\cdot 0467\,(\cdot 110+\cdot 012)\right\}=\cdot 798$$

∴ the oxygen must be 1 − ·110 − ·012 − ·798 = ·08 and the volumetric gas analysis should be:

CO_2 ·110; CO ·012; O ·080; N ·798.

Construction of Chart.—The result of the combustion of a fuel containing C and H can be readily shown by a combustion chart.

(A) Combustion of carbon to CO_2.

If C is burned to CO_2 in air, since the CO_2 produced is equal to the O used, nitrogen percentage remains unchanged. Take

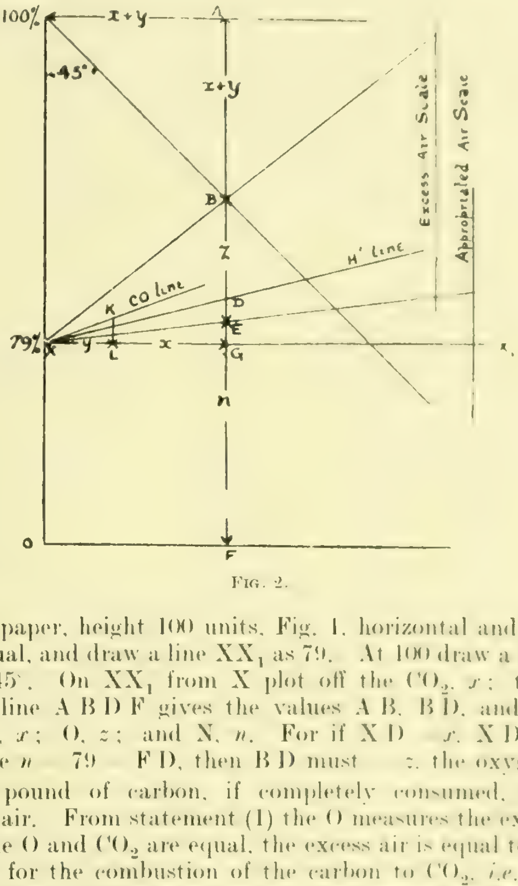


FIG. 2.

squared paper, height 100 units, Fig. 1, horizontal and vertical units equal, and draw a line XX_1 as 79. At 100 draw a diagonal line at 45°. On XX_1 from X plot off the CO_2, x; then the vertical line A B D F gives the values A B, B D, and D F of the CO_2, x; O, z; and N, n. For if X D = x, X D = A B, and since n = 79 = F D, then B D must = z, the oxygen.

One pound of carbon, if completely consumed, requires 11·5lbs. air. From statement (1) the O measures the excess air, and if the O and CO_2 are equal, the excess air is equal to the air required for the combustion of the carbon to CO_2, *i.e.*, in this case 11·5lbs. Taking any vertical line, measuring from XX_1, the line X B produced, if necessary, will cut this line, and the intercept is proportional to B D, and will, therefore, measure the excess air. When X D = D B, *i.e.*, when CO_2 and O are equal, X B is at 45, and should cut the vertical line at a point in the scale which reads 11·5. We can use the same scale divisions if we place this vertical line at a horizontal distance of 11·5 from X, and the line at 45° will then cut it at 11·5. This gives a convenient excess air scale per pound carbon burned. A number of scales may be placed at convenient distances from X, say, 2×11·5; ½×11·5, &c. These are shown on the Chart, Fig. 3, and the scales are convenient, as they involve no new horizontal lines.

(B) Combustion of 1lb. carbon to CO_2 and CO. H^1 available hydrogen also being burned.

From (7)

$$n=\cdot 79-\cdot 79\frac{y}{2}+\cdot 79\times 3H^1(x+y)$$

For any value of H^1 draw a line whose ordinates are $\cdot 79\times 3H^1(x+y)$, $x+y$ being measured from X along XX_1, Fig. 2. If the ordinates are calculated for $x+y=\cdot 21$, they will be found to agree very nearly with the scale divisions already adopted. Thus, for $x+y=\cdot 21$, $H^1=\cdot 1$, $\cdot 79\times 3H^1(x+y)=\cdot 04977$, very nearly 5 divisions. The scale shown on the chart should, therefore, be a

little to the right, say, at 21·1. Draw a line whose ordinates are $\cdot79 \times \frac{y}{2}$ + the CO line. When $y = \cdot20$ the ordinate is ·079. For any value of $x + y$ draw the vertical line A B D G F, the line X D being the H^1 line for the fuel as burned. Mark off $DE = KL = \cdot79\frac{y}{2}$. Also $GD = \cdot79 \times 3\,H^1\,(x + y)$.

$$\text{Then } GE = GD - DE = \cdot79 \times 3\,H^1\,(x + y) - \cdot79\frac{y}{2}.$$

$$FE = \cdot79 + GE = \cdot79 + \cdot79 \times 3\,H^1\,(x + y) - \cdot79\frac{y}{2}.$$

$$\therefore FE = n, \text{ and } AB = x + y. \quad \therefore BE = 1 - (x + y) - n = z.$$

$$= 11\cdot5 + \frac{11\cdot5}{x + y} \times \frac{n - \cdot79}{\cdot79} \text{ from (7)}$$

$$= 11\cdot5 + 14\cdot6 \times \frac{GE}{XG} \quad n - \cdot79 = GE \text{ and } XG = x + y.$$

To show this on a suitable scale for 1lb. carbon burned to CO_2, when CO is absent and $H^1 = 0$, the scale should read 11·5lbs., the weight of air required for the combustion of 1lb. carbon to CO_2. The additional air appropriated is $14\cdot6 \times \frac{GE}{XG}$, and is proportional to the ordinates to the line X E. If X G is made 14·6, the additional air is the ordinate at 14·6, and if X G

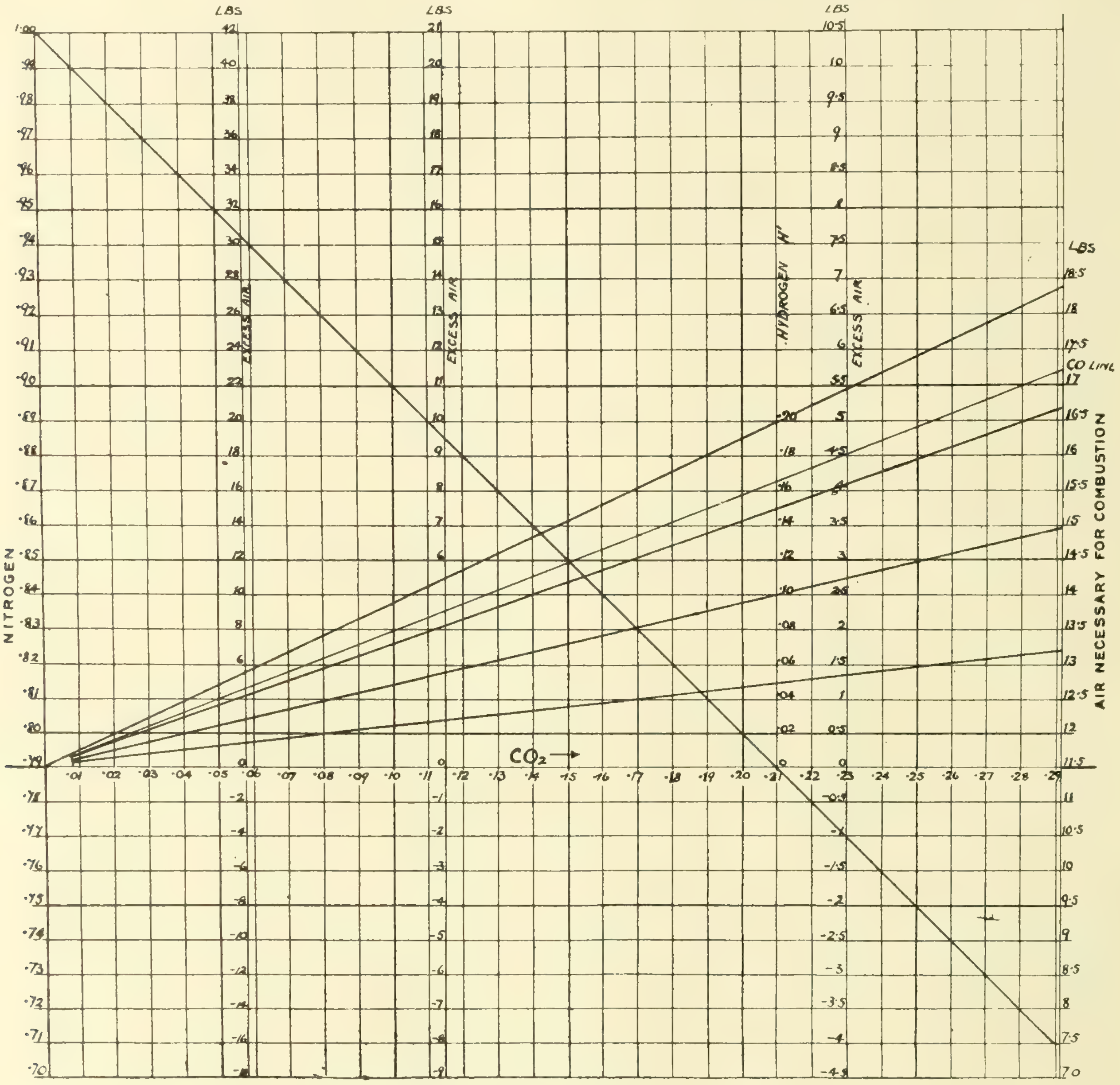


FIG. 3.—COMBUSTION CHART, PER LB. OF CARBON BURNED.

As before, the oxygen or B E measures the excess air. Through X draw lines X B and X E, and read off the excess air per pound carbon burned as the intercept between these lines on any convenient excess air scale. Air required or appropriated U for combustion of the fuel per pound of carbon burned—

$$U = \frac{100}{23\cdot2}\left\{\frac{8}{3}(1 - S) + \frac{4}{3}S + 8\,H^1\right\}, \text{ S being burned to CO.}$$

$$= 11\cdot5\left\{1 - \frac{S}{2} + 3\,H^1\right\}$$

$$= \frac{11\cdot5}{x + y}\left\{x + y - \frac{y}{2} + 3\,H^1(x + y)\right\} \text{ for from Statement II., or equations (2) \& (3), } S = \frac{y}{x + y}$$

$$= 11\cdot5 + \frac{11\cdot5}{x + y}\left\{3\,H^1(x + y) - \frac{y}{2}\right\}$$

is made 29·2 the additional air is half the ordinate at 29·2. To save confusion the scale is put at 29·2, the line XX_1 corresponds to 11·5lbs., and the scale shown in the chart is thus determined. The reading of X E produced on this scale gives the appropriated air or the air required, per pound carbon burned, for the combustion as it actually took place. In using the chart a line can be drawn for any given value of H^1. Some H^1 lines are shown for coal and oil fuels.

Taking the example already given, the intercept between X B and X E on the excess air scale = 7·45lbs.

$\therefore$ Excess air per pound fuel = 7·45 × ·792 = 5·9lbs.

The line X E gives on scale for the air required for combustion 12·6lbs.

$\therefore$ appropriated air, or air for combustion per pound fuel = 12·6 × ·792 = 9·95lbs.

The chart may be used in many ways. For example: (1) It may be used, as explained, to check the analysis of the gases, and obtain the appropriated and excess air in any case where the analyses of the fuel as burned, and of the resulting gases are given. (2) It shows the analysis resulting from the combustion, complete or incomplete, of a fuel with any given amount of excess air. (3) It may be used to obtain the air leakage into, say, an economiser. From the analysis at inlet and outlet, find the excess air at inlet and outlet, and the difference is the leakage. (4) It may be used to check the analysis of producer gas, and to determine the air used. &c.

LOCOMOTIVE CINDERS AS A FUEL FOR STEAM BOILERS.*

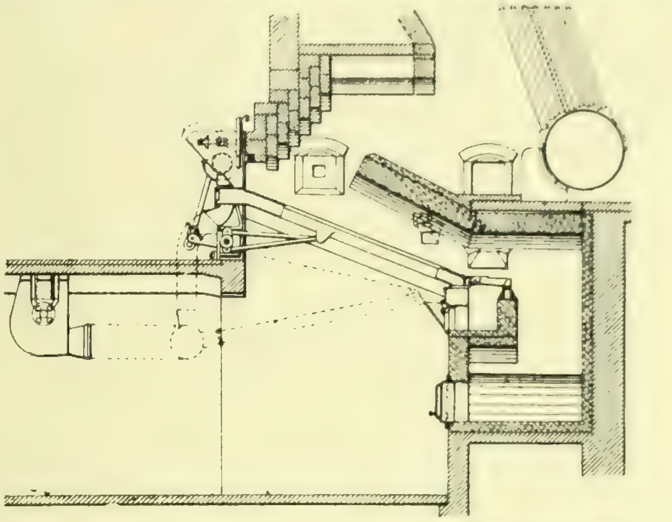
NUMEROUS attempts have been made to utilise for fuel purposes locomotive smokebox cinders, which contain from 6,300 to 8,100 B.T.U. per pound. But all such attempts have generally proved unsuccessful, owing to the difficulty of burning the cinders on any kind of grate, the grain of the cinders being very uneven, and varying from fine dust to pieces up to 5 mm. (or 0·2in.). Several experiments have been made on burning such cinders together with coal rich in gaseous compounds on undergrate blastfurnaces, such as the Kudlicz or Kridlo types, but these furnaces require that the charging, shifting of the fire, and removal of clinkers be made by hand; so that frequent opening of the fire doors allows the entrance of cold air with its attending heat loss, and at the same time makes it difficult to maintain an even fire. Even at that, the cinders do not burn well, and a large proportion of them are carried over into the ashes or sent out through the flue.

The tremendous amount of locomotive cinders obtained every year led the German engineers to experiment actively in order to find a system by which this kind of fuel could be burned without an admixture of coal rich in gaseous compounds. Attempts have been made to use special forms of arches, chain grates, inclined-step grates, and so on, but up to this time no attempts were successful in burning more than 40 per cent. of the cinders in a mixture of high gas coals. It was only lately that the State Railway Administration Division of Breslau, in installing a large roundhouse at Oels, again made a series of experiments on the utilisation of locomotive cinders for boilers with what appears to be fair success. They use a modified type of forced-draught furnace with travelling grate of the Pluto stoker type. With the ordinary type of the Pluto stoker, the operation was not quite successful, as notwithstanding the motion of the hollow grate elements, the cinders exhibited a tendency to bake together and in this way interfered with the travelling of the fuel over the grate, which very unfavourably affected the steam output of the boiler. Further, the baking of the cinders prevented the air from reaching the fuel, resulting in incomplete combustion and the passage of a considerable amount of the cinders into the ashes.

The main advantages were secured by the introduction of steam into the hollow grate elements. After this was done, the slags remained fluid and did not form clinkers on the grate elements, the travel of the fuel over the grate became better, and greater combustion velocities became possible. Further, the action of steam helped to obtain far more powerful combustion than was possible in the early experiments, the ashes were well burned out, and contained only little combustible material. The other modifications were of a secondary nature and referred to regulation of velocity, distance of motion of the hollow-grate elements, air pressure of the grate, &c.

These experiments have shown that with the modified Pluto stoker it is fully possible to obtain a comparatively good efficiency of combustion with locomotive cinders. The main element of success in this test was a continuous breaking up of the fuel by the relative motion of the hollow-grate elements which gave the air of combustion means of access to the fuel. The high combustion temperature required in this case has been made possible with the Pluto stoker by the use of a special fire return arch, Fig. 1 As shown, the brickwork is arranged in a manner such that over the upper part of the grate there is only quite a short arch, the only purpose of which is to protect the header and the pipe connections against the action of the hot gases. On the other hand, there is a long arch over the entire lower part of the grate, fairly close to the grate. The flames, therefore, travel not as in other systems of firing from the front backwards, but from the back forward, and a large amount of radiation is obtained, directed towards those parts of the fuel which have just reached the grate, so that the fuel has an opportunity to reach the temperature of ignition in the early zones of the stoker. With the gradual travel over its path of combustion, the fuel has plenty of time fully to burn out.

The tests showed that with this system of firing comparatively great efficiency was obtained with cinders as fuel. The slags and the ashes were well burned out and contained only



FURNACE OF MODIFIED PLUTO STOKER FOR BURNING LOCOMOTIVE CINDERS

traces of combustible material. The amount of ashes taken out by the flue was insignificant and contained little combustible material. The use of locomotive cinders on a modified Pluto stoker gives a considerable economy over a chain grate on which are burned locomotive cinders together with ordinary coal.

* From an article by O. Nerger in "Zeitschrift des Vereines deutscher Ingenieure," and reproduced from the February issue of the Journal of the American Society of Mechanical Engineers.

Trials of the "Calgarian."—The new Allan liner "Calgarian," built by the Fairfield Shipbuilding and Engineering Company, Glasgow, ran a successful series of progressive speed trials on the 16th inst. on the measured mile at Skelmorlie, and afterwards ran manœuvring trials on the Firth. The speed trials consisted of seven double runs on the mile, beginning at a speed of 11 knots and working up gradually to a speed of 21·25 knots. On the last double run the mean speed was 20·634 knots, which is a knot and a half more than that which will be required in regular service.

Smoke Abatement Bill.—Lord Newton's Smoke Abatement Bill, the text of which was issued on the 20th inst., seeks to simplify and strengthen the law relating to emission of smoke by extending to the whole country provisions based on enactments in force in the Metropolis and in some few local areas, the practical utility of which has thus been proved by experience. The operative clauses of the Bill seek on the one hand to secure construction of the furnace on the principle of consumption of its own smoke, and on the other to put the onus of proof of careful use and working on the person using and working the furnace. In order to protect any industry in which, from its nature or requirements, it is not reasonably practicable to secure smoke abatement, power of exemption by the Local Government Board after due enquiry is proposed to be given. The Bill further seeks also to confer powers upon county councils, to authorise local authorities to set up joint committees with the approval of the Local Government Board for dealing with the emission of smoke; and, following the analogy of the Alkali Acts to give the Local Government Board power to appoint trained inspectors who may prosecute offenders in cases where the local authority has failed to perform its duty in the matter.

THE CORROSION AND SPLITTING OF CONDENSER TUBES.*

BY SIR HENRY J. ORAM, K.C.B., F.R.S. (ENGINEER-IN-CHIEF OF THE FLEET).

THIS institute has taken up the question of corrosion of condenser tubes in great detail, having appointed a representative committee to deal with the matter The second report to this committee by its investigator, which was presented and read at the Ghent meeting last year, is a most valuable document to those interested in the question. The report was of special interest to the Admiralty, as it confirms Admiralty practice and experience of the last 20 to 30 years. On examining the last report of this committee, it is of interest to note the good results given by a condenser-tube alloy containing 2 per cent. of lead. Hitherto engineers have had a considerable prejudice against lead in the copper-tin-zinc alloys, and perhaps the prejudice was not very definitely founded, but the satisfactory results given by the alloy referred to above, and those given by a gun-metal alloy containing a small percentage of lead, at high temperature, should cause the prejudice to come under review, and some light appears to be forthcoming on this important matter. It is possible that the percentage of lead in such alloys must be confined within very narrow limits to give the physical qualities required, and that outside these limits the alloy is unsuitable for the purpose intended. If this view be correct, and the proper percentage of lead, and the limits of variation from this percentage that can be allowed, can be determined in the case of alloys intended for certain purposes, such as for use with high-pressure steam, a great want will have been met. This important subject, the influence of varying proportions of lead in small quantities on the physical qualities of the copper-tin alloys, might well receive more consideration from the laboratory workers, manufacturers, and engineers of this institute. In order that progress may be attained, and an improvement realised in the adaptability of a material to its designed end and practical use in engineering, close co-operation should exist between the scientist and designer, the maker and the user.

The number of papers read before this Institute dealing with the finished product on the practical side and from the user's point of view have been comparatively few, and on this account the remarks respecting condenser tubes which I propose to make may be of interest, for in this case it was only by such mutual co-operation and interchange of ideas that a real advance was obtained as regards increased reliability of these important items of a warship's machinery equipment. There is no part of the machinery of ships on which more thought and time has been bestowed, or which has a more far-reaching effect on the reliability of the machinery, than that seemingly simple article—the condenser tube. Although the corrosion of condenser tubes is a defect of serious importance, many of the worst troubles that the Admiralty have experienced with such tubes have not been from corrosion or perforation, but from splitting when at work, which is a far more serious defect. The number of failures of tubes due to corrosion and perforation is much in excess of the number that fail due to splitting, but the more serious consequences which result from splitting are such as place these defects in the front rank of undesirable occurrences. When a tube perforates or corrodes the hole first made is minute. It gradually gets larger with time, but before it becomes enlarged to any considerable size there are usually opportunities of detecting the presence of small quantities of salt in the feed water and boilers, and when such presence is discovered efforts are made to locate the tube which has failed, generally with success, so that it can be plugged temporarily and renewed later at a convenient opportunity. In the case of a split tube, however, water being in most cases inside, it is generally the case that the entry of sea water from the tube into the condensed steam space is considerable, and may even amount to water pouring into the steam space full bore, from each end of the tube, so that the amount of damage usually done in this way by a split tube is far in excess of that due to a perforated tube. In the effort to avoid the cause of this defect it will have to be borne in mind that the tube has to be soft and ductile, so that it will resist any tendency to splitting or flying, but at the same time it must not be too soft to resist the pressure of the packing material which is applied at the ends to prevent leakage. As these two requirements are necessarily mutually antagonistic, difficulty is found in uniting them in condenser tubes.

Condenser tube failures are of the greatest importance to the Navy owing to their ill-effects as regards corrosion of steel parts, priming, cleanliness of boilers, and in other directions. In 1899 such failures had become undesirably important, both on account of their number and the greater detriment resulting due to the rise of boiler pressure and the use of water-tube boilers. The Fleet were therefore given orders to report to the Admiralty each case of failure of a condenser tube, either by corrosion, perforation, splitting, or deformation, occurring in ships with 150lbs. boiler pressure or above. A number of standard questions have to be answered by the ships' officers making their report, including the position of the defective tube in the condenser, the length of time it has been at work, its maker, and other particulars, so that a post-mortem examination is held on each condenser tube which fails. By this means a large mass of information, as complete as can be furnished by sea-going ships, is accumulated; and by gradual deduction from these reports, supplemented by laboratory experiments, where indicated to be necessary, and by assistance step by step from the manufacturers, we see the direction in which to work to eliminate those defects which are due to known and remedial causes.

The efforts of the Admiralty to effect a reduction in the number of failures of condenser tubes on service, which have also caused them to consider the question of manufacture and the detailed testing of condenser tubes, have extended over a considerable time. We have not always at first been able to carry the tube-makers with us, and some noteworthy differences of opinion have manifested themselves among the various makers when approached by the Admiralty on apparently simple matters. These differences of opinion seem to indicate the desirability for greater co-operation among the tube-makers themselves and a greater interchange of ideas and experience, by which they themselves would benefit and their customers would also reap advantage. It is always difficult to convince a manufacturer who has been occupied for many years in making a speciality, such as condenser tubes are, and whose plant and methods are ordered and organised, that his products are susceptible of improvements, or that defects occurring on service can be reduced by improvements in the process of manufacture adopted by him. The Admiralty, however, have been successful in enlisting the hearty co-operation of tube-makers generally in this important naval requirement, and our thanks are due to them for their valuable assistance in arriving at the present comparatively satisfactory condition of affairs. One of the many orders issued by the Admiralty with a view of minimising corrosion in condenser tubes, is an instruction to ships' officers to drive the circulating pumps at high speed at frequent intervals, to clear tubes of cinders, &c. Although the second report to the Corrosion Committee appears to throw doubt on the influence of such matter in starting local corrosion, yet as the report also points out advantages, from the corrosion point of view, in keeping low condenser temperatures, and bearing in mind that any obstruction in the tubes reduces the flow of water and hence raises the temperature of the tube, the instruction is justified by this further consideration. In addition, a single line of flow for condensing water is pointed out as beneficial, and all these recommendations are worth bearing in mind and applying as far as practicable; but where high powers have to be squeezed into the minimum of space, as in warships, we cannot insist on such considerations, and are often thankful to be able to get reliable machinery at all in the space allowed. At one period the failure of condenser tubes, especially due to splitting, was so frequent and important that it really became a serious menace to the efficiency of the Fleet, and the engineering branch of the Admiralty were naturally

* Abstract of Presidential address delivered before the Institute of Metals, March 17th, 1914.

much pressed by their lordships to remove this serious cause of inefficiency; but a knowledge of the history of condenser tubes in H.M. Fleet at that time shows that everything practicable had been done according to the information available. It therefore became necessary for the stringency of the specification to be increased and the inspection of Admiralty overseers to be made more strict to eliminate defective tubes, both during manufacture and after delivery.

As the condenser tube has bulked so largely in the report of the Institute's Corrosion Committee, I propose now to give a brief account of the development of these tests and conditions during the last 25 years, and have referred to a few of the opinions which the tube makers have been good enough to favour the Admiralty with, this information being given in the hope that it will be of interest to various makers in comparing notes of their competitors' opinions, and also of advantage to the Institute generally. A complete account of the very large number of suggestions and opinions of tube-makers made in response to Admiralty enquiry would, I feel sure, be of interest and value, but the limits of a presidential address will not permit this. Prior to 1890 the condenser tubes in the Navy were made of the 70-copper 30-zinc composition; but owing to repeated failures of condenser tubes in the Fleet, the Admiralty specification was in that year revised, and the alloy altered by adding 1 per cent. of tin in lieu of 1 per cent. of zinc, the revised composition being 70 per cent. copper, 29 per cent. zinc, 1 per cent. tin. An effort also was made, even so long ago, to introduce a flattening test; but it was not embodied, owing to opposition on the part of the makers, and, instead, heating and jarring tests were introduced. In 1891 the quality of the copper used was specified to be not less than 99·3 per cent. pure, while a little later tubes which were too soft were guarded against by a clause specifying that they should be stiff enough to stand a packing being screwed up tight enough to hold 30lbs. pressure of water. The specification was next amended so as to require tubes drawn from billets to be accurately bored and turned before being subjected to the final draws. It was found that in making the shells from which tubes were drawn, the bore was frequently eccentric, and often excessively so, and therefore the finished tubes were often thin on one side, although the total weight per foot was correct.

The defect of splitting became very common with the development of torpedo-boat destroyer machinery, and in 1900 the tube makers were asked several questions by the Admiralty, among them being: (1) Whether boring and turning the shells before drawing would facilitate the rejection of those which may produce tubes likely to develop splitting? (2) Whether any alteration of the alloy was considered to be desirable, or whether the splitting might be due to impurities introduced with either of the elements employed? As regards 1, the replies indicated that some firms thought that boring might be advantageous, but the general opinion was against both boring and turning. As regards 2, no alteration of the alloy was suggested, except by one firm, who thought 1 per cent. of tin was a disadvantage, and that an alloy of 2 copper to 1 zinc would render splitting less frequent; while another represented that splitting must not be attributed to impurities in the metal.

In 1901 some important tests were introduced; among others: (1) A flattening test to one-half the original diameter without previous annealing. (2) Heating to a dull red heat without splitting. (3) Selected tubes to be sawn through and examined for internal defects. (4) The tubes should be drawn on a mandrel. The flattening test proved to be the most important addition, and produced a great stir among the tube-makers when the results became known, and rejections were common. Representations were made to the Admiralty by the tube-makers concerning the flattening test, with the result that after much consideration a letter was issued to the makers informing them that this test would not be enforced at present, as far as rejection was concerned, but would be continued to be made for Admiralty information. In acknowledging receipt of this letter, however, one firm stated that they were strongly in favour of this test, "which we consider to be both proper and desirable in order to ensure freedom from splitting when the tubes are in use."

In 1902 the condenser-tube makers were again asked to suggest alterations to the specification with a view to obviating splitting, pitting, &c. They were asked to remark, among other matters: (1) As regards any alteration proposed in the alloy. (2) On the tests then specified, and with regard to the flattening test then in abeyance, whether a bulging or a flattening test was preferred. (3) Whether they could supply tubes having a diameter within narrow-gauge limit. As regards 1, firms either considered the specified alloy suitable, suggested mercantile marine practice (70:30 alloy); or (*a*) One firm suggested 60:39:1 alloy, and offered to make tubes of this alloy, but later withdrew the suggestion. They also suggested 1 to 2 per cent. of manganese in lieu of tin. (*b*) Others suggested their various special tubes, but did not bring any proof that they would be superior to the Admiralty alloy. As regards 3, the firms could work to a margin ranging from 0·003in. to 0·01in. With regard to 2, most firms preferred flattening to bulging, but one firm preferred neither, stating that flattening and bulging tests encouraged the making of tubes of a semi-soft nature and of unequal densities throughout. The great majority of firms, after a short time, adopted more or less the Admiralty view, the use of electrolytic copper becoming more common, and the purest qualities of zinc and tin commercially obtainable being used.

In 1904 there was another revision of the specification, after personal visits to the firms by Admiralty overseers. The following stipulations, amongst others, were introduced: (1) The amount turned off and bored out of billets for condenser tubes should be sufficient to remove all surface imperfections. (2) The external diameter of the tubes to have a limiting variation of 0·005in. (3) The flattening test was reintroduced, $\frac{5}{8}$in. tubes to be reduced to $\frac{1}{2}$in. All tubes to be left 2in. longer than the required length, so that every tube could be tested. There was some opposition to these new provisions, the principal difficulty being as regards the boring and turning conditions, which, however, were retained.

A Machinery Designs Committee was at that time in existence at the Admiralty, consisting principally of engineers outside the naval service, and they recommended that the Admiralty should define the extent of the final draw in the manufacture of condenser tubes, and a letter was addressed in 1905 to four of the principal tube makers asking their opinion on this matter. At the same time they were also asked their opinion as to the exclusion of "scrap." In their replies the firms were all in favour of clean "scrap," and gave their list of draws. One expressed the opinion that the material used was far more important than the number of draws, and asked that the original flattening test should be reintroduced (*i.e.*, flattening to half the original diameter). All the firms were again consulted in 1906 as regards the advisability of specifying: (1) The draws of the last but one and last tubes, together with the dimensions at each stage. (2) The amount bored out of the castings to be not less than $\frac{1}{4}$in. diam. (3) The copper used to assay not less than 99·7 per cent. pure. (4) Scrap not exceeding 20 per cent. may be used, providing it is strictly limited to the ends cut from tubes during manufacture. (5) The flattening test to be applied to either end of the tubes, and the diameter of $\frac{5}{8}$in. tubes to be flattened to $\frac{7}{16}$in. The replies of the various firms were as follow: Only one firm objected to the limitation of scrap. Three firms objected to the draws specified. Three others were prepared to accept all the tests and requirements. Two others considered the purity of the copper required was too strict, and suggested 99·5 per cent.; while another considered 99·7 per cent copper a mistake, as it would involve the use of electrolytic copper, which they deprecated. One firm objected to the amount bored out; while another considered $\frac{1}{4}$in. was too much, and that $\frac{1}{16}$in. would be sufficient; and, lastly, one objected to turning the castings, but agreed that boring was beneficial, and also agreed with the purity of the copper required, and were prepared to agree to the draws specified, but considered that variation of hardness would result.

After considering these replies it was decided not to specify anything concerning the drawing of the tubes, and a specification for condenser tubes was issued in 1906, which included the following: (1) The copper to assay not less than 99·6 per cent. (2) Scrap to be limited to ends removed from process tubes, and not to exceed 20 per cent. (3) Total

impurities not to exceed 0·625 per cent. (4) The amount bored out of castiings to be not less than ¼in. of diameter. This revised specification has held good to the present date, with the addition that electrolytic copper may be used, and its success, when coupled with some improvements in condenser construction, has well repaid the time devoted to this important matter.

In 1908-9 many cases of split tubes occurred in a new battleship's condensers, and a suggestion was made to the Admiralty that a tensile test should be made instead of a flattening test. At this time it was desired to take the views of the tube makers on some other points; this proposal was included in the reference. The eight principal tube makers were therefore referred to in 1910, and they were also asked, among other things, whether they would propose any modification in the method of carrying out the specified flattening test. The replies indicated that three of the firms had no objection to a tensile test if applied to 1 per cent. of the tubes, but all the remainder were strongly in favour of the flattening test being retained, but made various suggestions for making the test with lever presses or drop hammers instead of the hand hammer. In the words of one firm, "it would be a great mistake to do away with the flattening test, which is an excellent proof of proper alloying." This firm further stated that the present specified impurities allowed—viz., 0·625 per cent.—might with advantage be reduced by one half. From the above it appears that the majority of the firms were in favour of the flattening test, and the Admiralty saw no reason for abandoning it.

It may be asked, what has been the practical result of these efforts on the part of the Admiralty and their tube-making collaborators? My opinion is that the most beneficial action taken by the Admiralty during recent years is the practice, adopted in 1904, by which a test-piece was allowed for on each tube for the flattening test, a small piece being left on extra to the proper length, these pieces being sawn almost through, but not detached from the tube, and subsequently removed.

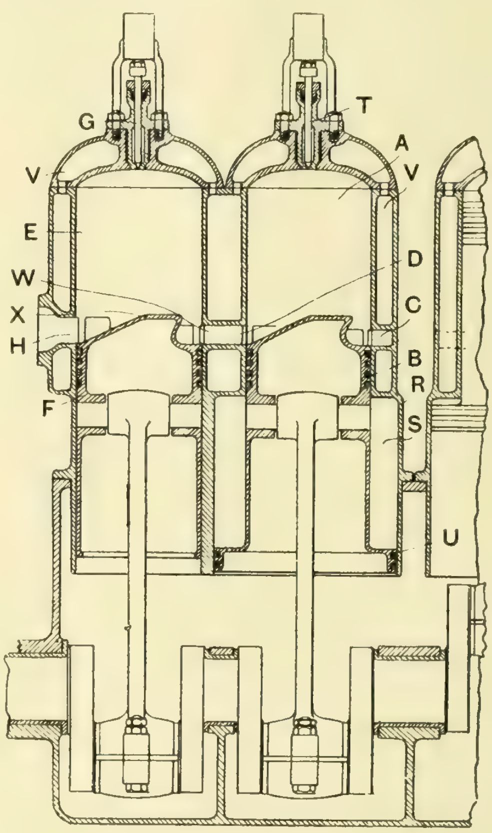
It is impossible to give the number of failures on service in the Fleet in detail, except in recent years. The earlier failures were very numerous. The following detailed figures are available as evidence that they have been reduced to more satisfactory proportions. In the year 1908, when the approximate number of condenser tubes at work at sea in the Britsh Fleet was 2,500,000, the number of failures of tubes occurring on service and reported were: Splitting, 21; corrosion and perforation, 69; total, 90; or at the rate of 1 in 28,000 per annum. During the next five years there was a very considerable addition of new condenser tubes in the ships added to the Fleet, owing to the great increase in horse-power of modern ships, also a considerable number of old tubes passed out of service. In the year 1913 the number of condenser tubes at work in the British Fleet was approximately 3,800,000, and the total failure of tubes during the two years 1912 and 1913 were: Splitting, 16; corrosion and perforation, 115; total, 131, or at the rate of 1 in 60,000 per annum—a very substantial reduction. A further point is, that of this proportion of 1 in 60,000, the majority are probably the older tubes which have been made under early specifications, and which have not had the present stringent regulations as regards treatment during manufacture and inspection applied to them. As these older ships and tubes fall out of service, the proportion of tubes which fail may be expected to be less even than this small figure. The ideal to work for is to reduce the failures to zero, but beyond a certain point further tests, restrictions, and additional precautions, both in treatment when at work and during manufacture, become so expensive as to be not worth the cost involved, in which case we must be satisfied with the success already achieved.

In view of the number of failures of condenser tubes caused by corrosion and perforation by salt water where the circulating water passes through the tubes, close attention has been recently given to endeavours to eliminate the causes of these perforations. An incipient cause of some of the cases appears to be the existence of original flaws or breakages of the inside surface of the tube, and to endeavour to eliminate such tubes the Admiralty have recently required a rigid internal examination. The result of this internal sighting has been to indicate defects in the tubes, and such tubes, on being cut up, have, in a large number of cases, revealed imperfections such as to justify their rejection and which, if these tubes had been fitted in place, would probably have caused early perforation.

ROOTS' TWO-STROKE CYCLE OIL ENGINE.

A PATENT recently granted to Mr. James D. Roots, of 58, Avonmore Road, West Kensington, London, W., relates to a new cycle of operations in oil engines and to the means for carrying the new cycle of operations into effect. In internal-combustion engines as hitherto made, a large amount of heat has been wasted in the exhaust, and it is this heat which the inventor proposes to make available in the new cycle of operations. The cycle is adapted to, or usable with, a two-stroke internal-combustion engine of the usual kind, but it is particularly applicable to engines in which the fuel is injected into the cylinder at or about maximum compression of the air charge, the type of engine usually called the Diesel, or the semi-Diesel.

The accompanying illustration, which is to a certain extent diagrammatic, shows a sectional vertical elevation of



ROOTS' TWO-STROKE CYCLE OIL ENGINE.

a two-stroke engine. A is the internal-combustion cylinder, B its working piston, C is the inlet port for scavenging air which may be delivered thereto from the crank chamber or from a separate pump. The internal-combustion cylinders are arranged in similar pairs, only one of which is shown. The other working cylinder is like the cylinder A formed with its lower end R of larger diameter. The working piston B has a lower trunk end of larger diameter U, working in the cylinder of larger diameter R, having the annular pump space S. The duplicate cylinder and piston partly shown in the drawings resemble those shown at A and B in all respects except that the piston is connected to a crank pin at 180° from the others, and consequently the pump or annular space S is at the top of its stroke, and in a position to deliver its charge of scavenging air to the port C, when the piston B is at the bottom of its stroke. In this position the exhaust port D is fully open. The internal-combustion engine cylinder, working piston, connection to crank, and means for injecting fuel, are all of known construction. Each annular pump chamber serves to deliver scavenging air to the next or adjacent working cylinder. The annular pump

piston U serves to deliver scavenging air to its next internal-combustion cylinder.

The steam-gas cylinder E is placed alongside and immediately adjacent the combustion cylinder A and the inlet W to the cylinder E is a continuation of the exhaust port D of the cylinder A. The piston F of the steam-gas cylinder E is formed with a similar deflecting or directing device X to direct the gases upwardly in the cylinder E, as in the combustion cylinder A. The injection valve G for water may be of a similar kind to the liquid fuel injection valve T in the combustion cylinder, but adapted to deliver a larger volume of water, and this water is supplied from the jacket V of the combustion cylinder. The water injection valve is operated in a similar manner, and from the same shaft as the fuel injection valve and approximately at the same time. The scavenging air is delivered to the port C at a slightly higher pressure and in rather greater volume than hitherto, so that the waste gases in the cylinder A are transferred, when the exhaust port D is opened, by the inlet port W to the cylinder E, completely displacing the steam and gases of the previous stroke through the exhaust port H of the cylinder E. The two pistons move upwardly together, the operations in the cylinder A are as usual in the Diesel engine. The waste gases in the cylinder E are compressed to a similar pressure to that in the cylinder A, and near the dead point of the stroke, near maximum compression, the water injection valve is lifted and the necessary quantity of water is injected into the cylinder. The heat of the gases plus that of the compression flashes this water into steam. A working down stroke is thus performed in both cylinders simultaneously. On the piston F uncovering the exhaust port H the steam and gases pass through the port, and this is immediately followed by the ejection of the remaining steam gases by the delivery of the exhaust gases from the adjacent combustion cylinder, when the cycle recommences.

THE STRENGTH OF WIRE ROPE.

THE results of an investigation of the strength and durability of wire rope made by Prof. G. Benoit at the technical high school at Karlsruhe are recorded in a recent issue of "Glückauf." The experiments were made with a patented cast-steel wire, 1 mm. diam., which showed a strength of 247,000lbs. to 255,000lbs. per square inch, with 227,000lbs. per square inch guaranteed. The wire was tested singly and also twisted to a strand of seven wires, 3·1 mm. diam., there being six steel wires and a core of a softer wire of a strength of about 122,000lbs. per square inch. This rope withstood a pull of 1,770lbs. The soft core did not break but stretched considerably. Three of the strands were then combined to form a rope of 6·8 mm. diam. and five to form a rope of 8·5 mm. diam., the latter with a hemp core. The wires and ropes were bent over a pulley through an angle of about 90° at the rate of 1,000 turns per hour, the turn meaning the bending of the wire from the straight and then back to the straight again. The stress to which the wire under test was generally subjected was 11,200lbs. per square inch. The single wires stood 198,710 bends; the twisted strand had one or two wires broken after 44,800 and 47,190 bends. The first experiment was made with a pulley 6⅞in. diam., and a larger pulley was then substituted, 7⅞in. diam. On this the single wire stood 122,000 to 200,000 bends; the twisted strand showed breaks in three wires after 40,860 bends. The cable of three ropes had one wire broken after 22,860 bends, and is said to have been destroyed after 36,440 bends. The five-rope wire began to fail after 35,000 bends and was given up after 40,000 bends. The conclusions so far seem to indicate that twisting leaves considerable strains in the wire rope and especially in those of high-class steel.

The Junior Institution of Engineers: North-Western Section.—A meeting of this section of the Junior Institution of Engineers was held at the School of Technology, Manchester, on March 20th., at which Mr. W. A. Tookey, M.I.Mech.E., M.I.A.E., of London, read an interesting paper on "Some Practical Notes on the Running of Gas Engines and of Gas Producers." An abstract of this paper is given on another page of this issue.

SUN POWER PLANT.*

BY FRANK SHUMAN.

THERE have been many intermittent efforts to utilise sun power in the past, but generally by isolated inventors who have never been able to go far enough to accomplish results from which industrial data could be gathered. The Solar Constant (or the amount of heat thrown by the sun on a given surface) has been many times determined by scientists. The latest determinations show that the heat received on a square centimetre of surface, above the atmosphere of the earth, is equal to 1·93 small calories per minute. This transformed into B.Th.U's. would equal 7·12 B.Th.U's. per square foot. Before this amount of heat reaches the earth where it can be utilised, it must pass through the atmosphere The atmosphere absorbs a greater or a lesser amount of this heat, according to its condition. If the air is clear and dry, considerably less is absorbed than if the air is loaded with water vapour and microscopic dust. This is a reason why for sun power we must go to those places in the Tropics where dry and clear air obtains.

Unless sun power can be utilised profitably, there is of course no incentive to spend work and money upon it. Therefore, the question of—"pounds, shillings, and pence"—is the all-important one. As our fuel costs absolutely nothing, the question of mechanical efficiency does not enter into the matter. It is a question altogether of the cost of the construction, upkeep, and labour. If the cost of construction of the sun power plant is so high that the interest on the extra investment (above the cost of a steam plant of equal capacity) will be so great that it cannot compete with coal—even at the point where coal is very costly—then there will be no incentive to go further. If a sun power plant cannot be so constructed that an ordinary engineer can run it, and that its wear and tear will be reasonable, and further, that excessive labour will not be required to handle it, then there is also nothing in it. These are the important factors to consider, and therefore it is necessary for me to give definitely the cost of the construction, maintenance, and labour, and to show definitely that sun power can be profitably produced throughout the vast areas in the Tropics where coal is very expensive.

I am told that all of the coal mined and oil produced throughout the entire world during the year 1909 would be represented by 270 million horse-power operating for 24 hours per day throughout the year. Assuming that sun power shall produce an equivalent amount, and basing our figures on the actual results already obtained by the plant at Cairo, then it will be only necessary for us to plant a square of 143 miles or 20,449 square miles of surface near the Equator with sun heat absorbers, spaced as wide apart as they are in the Cairo plant. Sun power plants need not compete with coal for the present at any of those tropical places near the coast where coal is reasonably cheap. At present we must confine our work to where the sun is at its best, and where coal is from £3 sterling even up to £8 sterling per ton. These prices of coal obtain through very large areas in the inland Tropics—areas, which, given plenty of mechanical power for irrigation, can be made to support large populations.

We started into the work of utilising sun power about seven years ago. Our work was first devoted to the determination of the amounts of heat obtainable from the sun which could be practically utilised. The first apparatus for determining this was a little "Hot Box" containing ether in which the number of heat units which could be caught on a given surface were determined. The next was a small apparatus of about ⅛ h.p., also running with ether. Then a considerably larger one of 3½ h.p. The reason that ether was used in all these preliminary experiments was that high pressure could be produced at fairly low temperatures. We knew, however, that ether as a means of converting heat into power was an inefficient fluid, and impracticable on a large scale, and therefore soon dropped it. We then constructed a whole series of various heat absorbers for generating low-pressure steam from water. These experimental absorbers finally resulted in the construction of a fair-sized sun power

* Abstract of paper read before the Manchester Association of Engineers March 14th, 1914.

plant at Philadelphia, which generated a maximum of 32 h.p. at mid-day, with an average of about 14 h.p. throughout eight hours of the day. From the experience gained in running this plant for one season, aided by the advice of Prof. C. V. Boys, of London, we constructed the sun power plant now in operation at Meadi, a suburb of Cairo, Egypt.

Steam can be generated from the sun's rays from water in a flat vessel painted a dull black, covered with two panes of ordinary window glass with an air space between, and protected against loss of heat by conduction and convection on the bottom, sides, and ends, leaving only the glass top fully exposed to the sunlight. We made many determinations of the amount of steam which could be produced in this manner, but found that in order to intercept a given area of sunlight in this way would cost considerably more than if we intercepted the sunlight by properly placed mirrors and we concentrated several square feet of sunlight on one square foot of boiler. Therefore our present plant at Cairo has five concentrations of sunshine by means of mirrors upon a centrally located boiler. No matter what kind of heat absorber was used, it must be turned to face the sun at all times throughout the day. To find a method of doing this in a simple and practicable way took much time and thought. The sun power plant was erected at Cairo because it was the nearest place to the Tropics easily accessible, though Cairo is by no means yet the ideal position for a sun power plant, as it is 30° N., and therefore the sun hits at a lower angle than it would further south. The Equator, of course, would be the ideal position for sun power plants, but up to 20° N. and 20° S. sun power is quite satisfactory. In fact, even at Cairo, good profitable work can be done by sun power plants.

Experience has shown us that low-pressure steam used at atmospheric pressure (14·7lbs. absolute) gives the greatest return in power per pound sterling invested. If we attempted to generate high-pressure steam we could easily do this by means of the sun's rays, even up to 500lbs. to the square inch. This, of course, would give us very high engine efficiencies, but, on the other hand, we would lose much more than we gain because, on account of the higher temperatures of the boilers, the losses by conduction and convection into the atmosphere would greatly increase. Also the cost of constructing the boilers owing to the strength of metal required would greatly increase, and, as stated before, the cost per foot pound of energy produced is the deciding factor. The engine is a special low-pressure engine designed by me to utilise low-pressure steam to the highest advantage, and this engine will give a brake horse-power with 22lbs. of atmospheric steam. The pump in the case of the plant mentioned is a reciprocating pump, but, of course, any sort of pump could have been used. On larger plants, I should use the low-pressure steam turbines.

Steam produced by the sun's rays is exactly the same as that produced by burning coal. The steam is generated in the sun heat absorbers, five in number, which are each 13ft. 4in. wide at the top, and 204ft. long approximate parabolic troughs for catching the sun's rays, and concentrating them upon the boiler swung at the focal point. The heat absorbers are placed about 25ft. apart in the clear, so that they will not shade each other when the sun is low in the morning and late afternoon. Their axes point north and south as does that of the earth, and they turn from east to west on their axes to face the sun. The mirrors are set in a light-steel framework, each one at the proper angle to throw the light upon the boiler, and consists of ordinary sheets of third-quality window glass about $\frac{1}{16}$in. thick, silvered on one side, and the silvering protected in the proper manner from the atmosphere. At the focal point of all of the light rays there hangs in the present plant a cast-iron boiler, which is tubular at the top and flat at the bottom where the water space is. This boiler is 15in. high, and it is hung on light rods in such a manner that the expansion and contraction will not interfere with it. These heat absorbers are set on crescents, which roll in a system of small rollers. Racks and pinions are provided for turning the sun heat absorbers from a low eastern aspect in the morning to a low western aspect in the evening. The heat absorbers are turned by the engine by the ordinary shaft drive and friction clutch. An adaptation of the thermostat throws this friction clutch in and out. The thermostat is located right under the boiler. As long as the thermostat is in the shade, this means that the heater is pointing correctly at the sun. When the sun moves ahead a little, and the edge of the sunlight strikes the thermostat, it immediately throws the small friction clutch in and then the heat absorber turns westward a fraction of an inch or so. As soon as the thermostat is again in the shade the clutch is released, and the sun heat absorbers stand still. In this way by short intermittences the heat absorbers are always kept facing the sun throughout its course during the entire day. The thermostat acts very satisfactorily.

In the morning—according to the degree of latitude—the heater will start to make steam. At Cairo it would start to make steam in midsummer at 7-30 o'clock, and will make steam in quickly increasing quantities until the maximum would be arrived at between 10 and 2 o'clock. Then the amount would gradually decrease until 5-30 in the evening. Tests of the steam-producing capacity of this heater, made by Mr. A. S. E. Ackermann, of London, show that the average production would be 1,100lbs. per hour of 15lbs. (absolute pressure) steam for a 10-hour day. In other words, the plant at Cairo is capable of giving on an average 50 b.h.p. This same plant located 1,000 miles or so further south, should give about 65 b.h.p. The steam in the boiler is produced at practically atmosphere, although the engine will do good work when the steam is at considerably lower pressure. For instance, if a cloud passes over the sun for, say, 10 minutes, then the engine draws on the reserve of steam held in the boiling water contained in the boiler, and will lower the pressure down to 4lbs. absolute, before it would come to a stop. Early in the morning and late in the afternoon the engine also runs at pressures considerably below the atmosphere, giving a corresponding amount of power.

The boilers of the present plant are surrounded by a single thickness of thin window glass, which is placed there for the purpose of cutting down the loss by conduction and convection, particularly when the wind is blowing strongly. In future plants it is intended to dispense with this glass and bring the number of concentrations of sunlight up from five to ten. The heaters are so constructed that they will stand a wind pressure of 30lbs. to the square foot safely. All of the mirrors and glasses used in constructing these heat absorbers are held in place by means of small brass springs, so that they are set in a very flexible manner. It will, of course, be asked what will be the effect of dust settling on the mirrors, and on the glass. Any dust settling, of course, cuts off the light according to the thickness of its layer, and loss of light means loss of power. Therefore, we must keep our mirrors clean. Labour is very cheap in the Tropics, and 20 pence a day to do this work would suffice to keep the mirrors entirely clean, the proper washing arrangement, of course, being provided. Resolved to its first principles, sun power is a very simple proposition: Provide a boiler; throw plenty of sun's rays upon it; and generate your steam. If you choose to, you can throw sufficient sun's rays upon it to melt the boiler down. As a matter of fact you can concentrate until temperatures higher than in the electrical furnace are obtained.

You may ask, what will our sun plant do when there is no sun? Of course, when the source of our supply of power is cut off we cannot get it. But we can do what is done in a great many other lines, and that is, store it. Of course, the sun power plant can be built large enough to manufacture electricity and put it in a storage battery from which the plant could be run during the night, or rainy weather. But a storage battery of the necessarily large capacity is altogether too expensive, and it would never do to suggest anything so complicated as this for the Tropics. Therefore we will use for the storage of power an already well-tried but much simpler system. That is, we will store in large tanks properly insulated from the atmosphere, the necessary quantity of water at the boiling point. From this water we will draw during the night or during a rainy day, low-pressure steam and with this run our engine, which is constructed so as to run economically down to 4lbs. absolute. In other words, as the vacuum in the condenser draws through the engine upon the water in the tank, the water which is first at 212° Fah. will generate low-pressure steam until it drops down to 150° Fah., or even lower, and this heat is turned into power by the engine. We do not advocate the storage of power in this manner for a longer period than

three days, although in exceptional conditions this time may be increased to six. We did not connect a storage tank with our present plant, because we were mainly after a record in power producing results.

It will occur to you that sun power plants occupy an enormous amount of room per horse-power. This is quite true, but in the locations where we are suggesting their use, land is very cheap indeed and the amount of room occupied is not a great disadvantage. As the cost of upkeep is an important factor, the heat absorbers are constructed entirely of reinforced concrete for the foundations; steel for the frame; cast iron for the boilers; and glass for the mirrors and boiler covering—all of which materials are practically indestructible in the Tropics, barring accidents. In order that you may get an idea of the present possibilities of sun power, I will say that the sun heat absorbers at Cairo can generate steam for 50 b.h.p. for 10 hours every day the sun shines. The steam-producing part of this plant will cost erected in the Tropics, according to a careful estimate, the sum of £1,560, being at the rate of £31 per brake horse-power. The boiler, stack, and buildings of a coal-burning plant to generate the same amount of power for 10 hours per day throughout the year would cost £770.

We now have the following comparisons:—

Sun Power Steam Generator Plant working 365 days for 10 hours per day:—

	£	s.	d.
Interest on Capital Expenditure £1,560 at 5 per cent.	78	0	0
Wear and Tear Depreciation at 5 per cent.	78	0	0
Total	£156	0	0

Coal-burning Steam Generator Plant working 365 days for 10 hours per day:—

	£	s.	d.
Interest on Capital expended £770 at 5 per cent.	38	10	0
Wear and Tear Depreciation at 5 per cent.	38	10	0
Coal consumption at 2lbs. of Coal per brake horse-power—163 tons at 9s. 8¼d.	79	0	0
Total	£156	0	0

The above comparisons show that the sun power steam generator will compete in the Tropics with a coal-burning steam generating plant which can obtain its coal at only 9s. 8¼d. per ton delivered to the furnace doors. Any excess in the cost of coal burned beyond this figure is clear profit in favour of the sun power plant, and as the cost of coal in the more favourably placed in the Tropics where sun power plants will be built for the present may be taken at no less than £3 per ton, the saving would be as follows:—

Cost of Working Coal-burning Steam Producing Plant as above:—

	£	s.	d.	£	s.	d.
Interest and Wear and Tear Depreciation	77	0	0			
163 Tons of Coal at £3	489	0	0			
				566	6	0
Cost of Working Sun Power Steam Producing Plant				156	0	0
Total saving				£410	0	0

The above shows that with coal at £3 per ton, there is a saving of £410 per annum (or nearly 52 per cent.) on the extra cost (£790) of the sun power plant over that of coal consuming plant, which would mean that in less than two years the saving in fuel effected by its use would cover this extra cost. Now the above figures are based on ideal conditions, and we are wrong in assuming that we will meet these ideal conditions always in actual practice. For instance, when the sun is overcast by clouds, this cuts off from the gain, but the margin is so great that I feel quite sure that at the present time at the proper tropical places sun power is a most remunerative field for engineering research and work. In a place where during the 10 hours of the day on which we are counting, the sun is overcast 10 per cent. of the entire year, then we are, of course, only going to get 90 per cent. of the results given above. If the sun is overcast one quarter of that time, then we are going to get 75 per cent. of the results just given. It must be our aim during the infancy of sun power to locate where we can count with safety on at least 90 per cent. of sunlight throughout the 10 available hours of the day throughout the year, and the calculations given above amply allow for this, and leave profits sufficient to justify engineers to work further in sun power.

The heat absorbers of the Philadelphia (1911) predecessor of the Cairo plant had a thermal efficiency of 13 per cent. The Cairo plant has a thermal efficiency of 57 per cent., showing that in two years' time we have increased the thermal efficiency of sun power from 13 per cent. to 57 per cent. By this is meant that out of a hundred heat units which reach the surface of the earth, 13 per cent. and 57 per cent. respectively were turned into steam and used in the engine. We have every reason to believe that in future installations our thermal efficiency will increase easily up to 80.

POWER ECONOMICS FOR INTERMITTENT LOADS.*

BY E. IVOR DAVID, A.M.I.E.E.

(Concluded from page 267.)

A FURTHER instance may be given of a colliery on a slightly smaller scale. Power is available at a low rate in connection with a waste heat scheme which takes gas from coke ovens belonging to the colliery, and offers power up to a certain maximum at the rate of about ·25d. per unit. The maximum weight of coal wound per day will be 3,000 tons in 15 hours. About 10 per cent., or 300 tons, of this would be coked, and the gas available, assuming that the ovens are of the waste-heat type, would be capable of evaporating 500,000lbs. of water per day. If the ovens are of the regenerative type, gas engines may be used as prime movers. This supply of gas would be more or less continuous throughout the 24 hours, but the charging of the ovens could be so arranged that the maximum quantity of gas of the highest calorific value, that is, the gas given off during the earlier period of coking, would be available during the period of maximum load on the generating plant.

The depth of shaft is 1,560ft., and the weight raised per wind four tons. Fig. 5 gives details of velocity, torque, and kilowatt input to the winding motor, the control being on the Ward-Leonard principle. Owing to the small pit shaft diameter it is necessary to use a four-deck cage carrying eight trams, each having a 10cwt. load. The four decks have to be unloaded in succession, and cages moved each time. The minimum time in which this can be done is 22 seconds. The actual wind would take 45 seconds, making a total of 67 seconds per wind, giving 54·6 winds, or 218 tons, per hour, allowing a slight margin for the maximum rate of 200 tons per hour necessary to raise 3,000 tons in 15 hours. The drum would be cylindrical, 14ft. diam., running up to a maximum speed of 79 revs. per minute. Two direct-current motors would be direct coupled to this drum, and a Ward-Leonard motor generator set, comprising a 1,260 kw. generator, a 35 kw. exciter, and a 1,200 h.p. 6,000-volt induction motor running at 800 revs. per minute would supply power at varying voltage to the motors. No flywheel balancer is included, as the station has ample capacity for the peak loads. The average kilowatt consumption of the above plant, including compressor motor and other auxiliaries, would be 520 kw., which is equivalent to 2·39 units per ton of coal raised, an overall efficiency of 54·3 per cent., or a consumption of 1·375 units per shaft horse-power. The addition of a flywheel weighing 27 tons, with its resultant losses in bearing friction, windage, and slip regulator, would increase the consumption to 577 kw., the light load losses in the flywheel alone amounting to 37 kw. The cost for power for winding would be (allowing three hours per day for winding men): $(520 \times 18 \times \cdot 25) = 2{,}320$ pence, or ·78d. per ton of coal raised, that is £2,420 per annum. The cost of the complete electrical equipment, with winder, drum, compressor plant, Ward Leonard set, switch gear, cables, and erection, would be £8,630.

* Paper read before the Rugby Engineering Society, March 10th, 1914.

A steam plant for the same output, having a pair of high-pressure engines of the latest type, 30in. × 72in., or 33in. × 60in., with drop valves and a cylindro-conical drum increasing from 14ft. to 20ft., would cost £4,500 to £5,000. For each wind this engine would require about 300lbs. of steam, and for banking from the four decks (allowing 25 to 30 seconds, as the steam engine would not be able to accelerate so rapidly as the motors, and would therefore be under full steam for at least 10 seconds) a further 50lbs., which is a very moderate estimate, or a total of 350lbs. per wind, which for 53·7 winds per hour amounts to 18,800lbs. Losses in condensation, brake gear, and auxiliaries would probably bring this up to 20,000lbs. per hour. To supply steam to this engine, three 30ft. × 8ft. Lancashire boilers, with a fourth as a spare, would be required. With gas-burning furnaces these would be worth at least £1,100 each, including foundations, &c., making a total of £4,400 for boiler plant, including feed pumps; piping, &c., would cost at least a further £300. The total for engines, boilers, &c., would therefore be £9,200 minimum, or slightly greater than the electrical plant. The exhaust steam from these engines would be sufficient to generate the necessary power for the remaining colliery load, but additional capital cost will be incurred in the provision of the plant. An accumulator, a 600 kw. mixed-pressure turbo-generator, with condensing plant, switch gear, build-

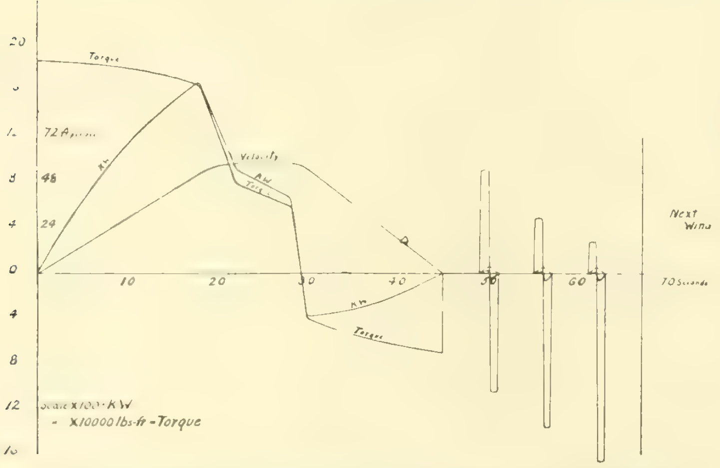


FIG. 5. CURVES OF DRUM TORQUE, ROPE VELOCITY, AND K.W. INPUT TO WINDING MOTOR. Diameter of drum, 14ft., depth of shaft, 520 yds.; 4 tons per wind; 215 tons per hour.

ings, foundations, &c., would cost £6,500. The colliery load would be about 300 kw., that is, a load factor of 50 per cent. Thus the total capital cost for the steam winder and accessories would be £15,700.

The cost of running the steam winder plant and accessories, including wages, interest and depreciation, stores, repairs and renewals, &c., would be £3,500 per annum. Running the electric winder would cost, including the same items, £1,400 per annum. To this must be added the cost of power for the winder, and also for the colliery load, obtained in the case of the steam winder from the turbine set. Taking the colliery load 18 hours full-load 300 kw., six hours half-load 150 kw., the annual consumption would be 1,575,000 units at ·25d. = £1,640, making with the winder power cost of £2,420 a total of £4,060 per year of 250 working days. Against this must be set the value of the gas sold to the Power Company in the case of the electric winder, but used in the boilers in the case of the steam plant. The value of this gas at ·005d. per pound of water evaporated would be £2,600 per annum. The net cost of power would therefore be £1,460, giving a total running cost for the electric winder of £2,860 per annum, an advantage over the steam set of £440 per annum. The electric plant has the advantage of ample safeguard against failure of supply, as the Power Company has a large reserve plant, while there is no standby generating plant included in the steam equipment. It also offers the advantage in this instance of lower capital outlay, an argument which usually applies against it.

An increase in the colliery load or a decrease in the value of the gas sold might reduce the margin in favour of the electrical equipment, but an increase in the colliery load would necessitate standby generating plant for the steam winder equipment, and a decrease in the value of the gas would probably be accompanied by a reduction in the cost of power per unit. The absence of a generating station at the colliery, with the necessity of constant care to keep generating costs down, would be appreciated by colliery engineers, and would allow them to concentrate their attention on the economical and reliable operation of the mine.

Another case is that of a small colliery raising about a quarter of a million tons per annum from a depth of 600ft. The existing engine is obsolete and inefficient, all the rest of the plant is electrically driven, power being purchased from a large supply company. 3,600 tons of coal per annum are used under the boilers for this engine, and the total running costs amount to £2,300 per annum. This includes wages and repairs, but no interest or depreciation. An electric winder on the Ward-Leonard principle for this output would cost £3,300, including mechanical and electrical parts; alterations to foundations, engine-house, &c., would cost, say, £700, making a total of £4,000. The consumption of power, when winding at the rate of 125 tons per hour, would be 1·32 units per ton, for 250,000 tons per annum this = 330,000 units at ·45d. per unit, £620 per annum, say £650, allowing for standby losses.

Labour, repairs, and renewals	£250
Interest and depreciation	400
Making a total of	£1,300

that is, a saving of £1,000 per annum. These examples show that, commercially, electricity for main winding deserves consideration in every case, and in most shows a decided advantage.

The conditions and loads in rolling mills are different from winding engines. Rolling mills are of two general types, continuous running and reversing. Fig. 6 shows a set of continuous indicator cards taken from a tinplate mill of the former type. This engine has cylinders 16in. and 32in. diam. × 4ft. stroke, and runs normally at 30/40 revs. per minute. It is throttle-governed, with a constant cut-off at about 60 per cent. of the stroke on the high-pressure cylinder; between the passes steam is throttled and excessive wire-drawing takes place. The efficiency would be very much improved by a variable-expansion governor. The engine is assisted during the peak load produced by the earlier passes by a flywheel 24ft. diam., weighing 50 tons. The fall of speed produced by the passage of the bar through the rolls enables the flywheel to give up its energy, which is restored during the idle periods between the passes. The total steam consumption over the rolling period for one bar was 19lbs., and the time 22 secs. The average indicated horse-power 160, therefore the average consumption per indicated horse-power per hour shown on the indicator diagram is 19·5lbs. When allowance is made for cylinder condensation and other losses, probably not more than 75 per cent. of the steam used appears on the diagrams. The actual consumption would be 29lbs. per brake horse-power per hour, assuming a mechanical efficiency of 89 per cent. The cost of this engine, with steam piping, condenser, foundations, &c., would be about £2,600. The flywheel, with shaft, bearings, and foundations, &c., would cost £800, a total of £3,400.

This mill could be driven by an induction motor and suitable reduction gearing. The overall efficiency of motor and gearing would be about 86 per cent., that is, the consumption at the turbine supplying the motor, assuming 16lbs. per kilowatt-hour, would be 14·0lbs. per brake horse-power per hour at the rolls. Assuming that the generating plant exists, the capital cost of an induction motor, with starter and slip regulator, flywheel, reduction gearing, foundation, &c., would be £4,300.

Owing to the small speed variation of an induction motor from no-load to full-load, it is necessary to provide some device to produce a speed drop during the peak loads; this can be effected by the use of a suitable automatic regulator. Contactor type slip regulators have been made, which operate in one cycle on a 50-cycle supply, that is, in one-fiftieth of a second. This has proved sufficient for the most

severe rolling mill purposes. Ordinary motor-operated slip regulators of the liquid or metallic type are somewhat sluggish in their action, and do not give satisfaction when used for rolling mill work.

Direct-current motors are also employed for driving continuous-running rolling mills. When used in conjunction with flywheels, the addition of series windings to the main field produces the necessary speed drop with increase of load. The speed horse-power curves of a compound wound motor and of an induction motor are of the forms shown in Fig. 7. The speed drop can be increased by increasing the number of series turns in the case of the direct-current motor, or the rotor resistance in the case of the induction motor.

In merchant mills which usually roll a great variety of sections, it is an advantage to be able to vary the speed of

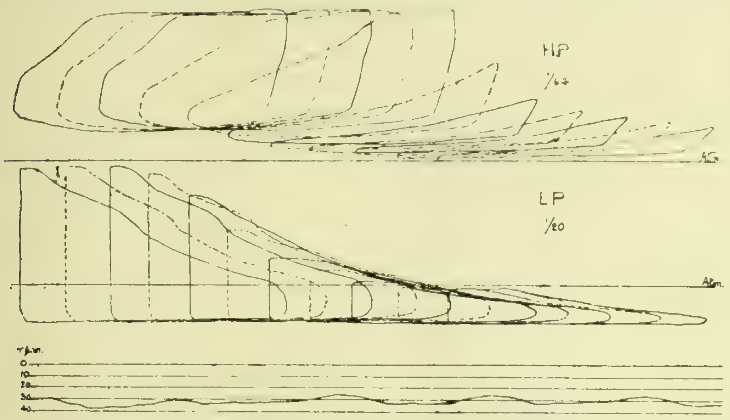


FIG. 6.—ENGINE A. TWO MILLS ON DOUBLES.

the mill motor. The speed of direct-current motors may be easily and economically varied by field regulation. Alternating-current motors can be built to run at two or more definite speeds by providing them with special windings, but actual speed variation from synchronous speeds can only be obtained either by insertion of resistance in the rotor circuit or by auxiliary machines.

When electric motors were first proposed for reversing rolling-mill drives, the existing engines were of a most uneconomical type, usually two-cylinder high-pressure; and it was an easy matter to prove that an enormous saving could be effected by the electric installation, but competition has resulted in a great improvement in the type of engine and its steam consumption. Modern engines are usually of the compound type, condensing or non-condensing. High starting torque is obtained by a stop valve in front of the low-pressure cylinder acting in conjunction with the main stop valve. When the engine is stopped, the steam from the receiver to the low-pressure cylinder is shut off. This forms a back pressure or cushion for the high-pressure cylinder and assists to bring the engine to rest. In starting, this high receiver pressure enables the low-pressure cylinder to assist the high-pressure cylinder, provided that the duration of stop is not great. Late cut-off is essential in a reversing engine to enable it to exert a heavy starting torque at any point in a revolution, but late cut-off is opposed to steam economy, therefore once the ingot is gripped and the mill speeded up, the engine must be adapted to the power requirements of the mill by adjustment of cut-off.

In a cogging mill, particularly during the earlier passes, the number of strokes per pass is very few and adjustment of cut-off is practically impossible, but in a roughing or finishing mill where the passes are longer, economy may be effected in this way. Cogging-mill engines are therefore usually of the simple high-pressure type, the refinements being introduced on the roughing and finishing mill engines.

A typical modern rail mill for an output of 3,000 tons per week would have the following steam equipment:—

36in. Cogging Mill.—A three-cylinder reversing engine with cylinders 40in. diam. by 4ft. stroke would be used. With a boiler pressure of 150lbs. per square inch and a consumption per indicated horse-power per hour of 45lbs. of steam the consumption per hour of this engine would be 17,000lbs. to 20,000lbs.

30in. Roughing Mill.—A two-crank, four-cylinder tandem compound reversing engine with cylinders 30in. and 54in. diam. and 5ft. stroke would be used and take about 30lbs. of steam per indicated horse power hour, when running under its best conditions. As the load is of a very intermittent nature, and during the earlier passes a very late cut-off is necessary, its consumption per hour would be 25,000lbs. to 30,000lbs.

30in. Finishing Mill.—An engine similar to the roughing mill engine could be used, but as the maximum load on this engine would not be as high as that of the roughing mill the average steam consumption would be lower, amounting to 20,000lbs. to 25,000lbs. per hour. The total steam consumption, therefore, for the complete mill at the above output, which is equivalent to about 300 tons per shift, would be 60,000lbs. to 70,000lbs. per hour. It would be impossible to have the boilers near all the engines, therefore the losses in steam pipes and connections would be high, and at least seven or eight boilers 30ft. x 9ft. would be required to supply the mills.

The average coal consumption per ton of standard rails rolled from 2 or 3-ton ingots, is 5 cwt. in the case of steam-driven mills. Assuming a 10-hour shift rolling 30 tons per hour, the steam consumption per ton of finished rails would be $\frac{70,000}{30}$ 2,340lbs. This amount could easily be produced by 5 cwts. of coal and leave a margin for banking, &c., over the week-end. The live rollers, transfer tables, shears, saws, &c., would be electrically driven. The exhaust steam from the above mills would be passed into an accumulator and thence into two 1,000 kw. or one 2,000 kw. mixed-pressure turbo-generator. Allowing for losses in piping and accumulator, and for wetness of steam, about 1,750 kw. would be generated.

The capital cost of the complete equipment would be, say, £6,500 for the cogging engine; £8,500 each for the roughing and finishing engines; nine boilers (one standby), say, £9,000; an accumulator, two 1,000 kw. turbo-generators, with condensing plant, piping, &c., £11,000; steam and exhaust piping, valves, &c., or a total of £45,500, excluding cost of foundations, building, &c.

For the same output the electrical equipment would be as follows: The cogging mill would be driven by one motor and the roughing and finishing mill by another motor, which may be a duplicate. More work would be done on the ingot in the electric cogging mill than in the steam mill, thus reducing the load on the electric roughing and finishing mills. The motors would have a capacity of 3,500/11,000 h.p., at 70 revs. per minute, 1,000 volts. During the later passes in the finishing mill the motor could be speeded up to 150 revs. per minute. Either motor would be

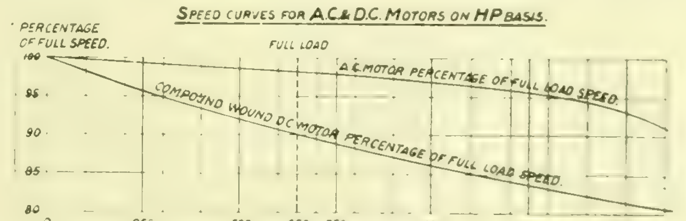


FIG. 7.

capable of making at least 20 complete reversals in one minute. They would be controlled on the Ward-Leonard system and each supplied with current by a 3,000 kw., 1,000-0-1,000-volt generator driven by a 1,200 h.p. induction motor. Flywheels of 30 to 40 tons weight, and 13ft. to 14ft. diam., would be coupled to the generators to assist the induction motors during the peak loads. The motor generator sets would run at 490 revs. per minute normally. The Ward-Leonard generators would have differential series field windings, which would be so arranged as to limit the maximum current flowing between motors and generators, thus the machines could not be injured by careless operation of the controller. Slip regulators would be provided for the induction motors. The two motor generator sets would be arranged so that they could be mechanically coupled together when both are running, thus averaging the load and reducing the amount of slip normally required. It should be noted that the generators and mill motors are rated on the

root-mean-square value of the armature current, while the induction motor rating is based on the root-mean-square horse-power. Owing to the slow speed of the mill motors, forced ventilation would be necessary to maintain reasonable working temperatures; motor-driven fans with air filters would be provided for this purpose. Exciters, barring gear, oil pumps, and other auxiliaries, switch panels, and control gear, &c., would be included in the equipment. The total cost of such an equipment erected, but exclusive of buildings or foundations, would be about £29,000.

The power consumption for the mills would be 30 to 40 Board of Trade units per ton of rails from 100lbs. to 50lbs. per yard, for an output of 30 tons of rails per hour the average power consumption for varying sections would be 1,050 kw. The auxiliaries would require a further 4·5 units per ton, or 140 units per hour, making a total of 1,190 kw. for the whole mill. This would require 19,000lbs. of steam per hour at the turbines.

The power consumptions for various size billets are given

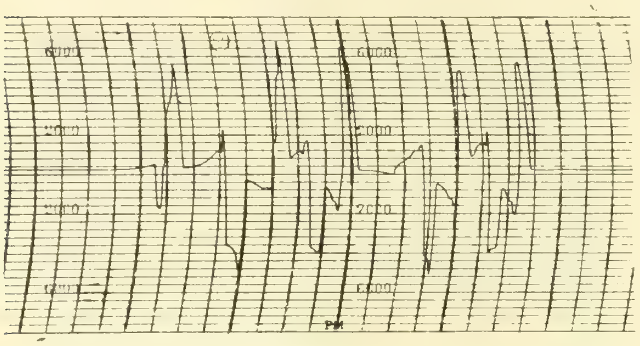


FIG. 8.

in Table II., abstracted from the "Iron Age." These tests were taken on the 41in. reversing rolling mill at Julienhutte. The two mill motors are each 1,000/3,000 h.p., 65/90 revs. per minute, and are supplied by 1,450 kw. generators coupled to flywheels and driven by 1,000 h.p. induction motors. Fig. 8 shows a recording ammeter curve taken from a 28in. reversing cogging mill motor, 1,000/3,600 h.p., at 70/120 revs. per minute. This shows the nature of the loads and the very rapid reversals which can be effected by these motors.

TABLE II.—*Details of Tests each Representing One or Two Complete Heats.*

Section of final bar (ingot 22·05in. by 22·05in.).	Increase in length times.	Time. Mins.	No. of ingots.	Weight after deducting heating loss. Lbs.	Current Consumpt'n Per ton. Kw.-hours.
2·5 sq. in.	79·0	124	13	112,810	43·9
5·1 ,,	18·6	85	17	146,099	22·7
4·7 ,,	21·8	45	10	91,050	22·1
7·1 ..	9·7	77	20	181,395	15·4
3·1 ,,	49·0	148	20	179,940	36·1
2·5 ..	79·0	97	10	87,963	45·9
3·9 ,,	31·4	110	19	173,127	29·5
4·7 ,,	21·8	52	10	92,086	22·8
8·3 ..	7·1	64	20	186,510	14·1
3·1 ,,	49·0	77	10	86,090	35·2
4·7 ,,	21·8	110	20	184,172	22·7
3·9 ,,	31·4	63	10	89,198	28·8
7·1 ,,	9·7	48	10	91,248	21·1
7·1 ,,	9·7	88	20	182,695	16·9
2·5 ,,	79·0	95	10	83,179	46·1
9·8 ,,	5·0	41	13	100,622	13·3
9·8 ..	5·0	63	20	157,827	15·7
9·8 ,,	5·0	31	12	79,277	13·2
4·7 ,,	21·8	55	9	81,041	23·2

In a modern steelworks, power for supplying electrically-driven mills would be generated by gas-engine-driven alternators, using blastfurnace gas, or steam turbines, using steam generated in gas-fired or waste-heat boilers. The distance separating the blastfurnace plant and the rolling mill is immaterial, as electric power can be economically transmitted through any probable distance. The gas from blastfurnaces having a capacity of 500 tons of pig iron per 24 hours, and suitable for supplying the steel-melting plant for the above mills, would be sufficient for blowing engines, stoves, &c., and still leave an ample surplus. Assuming that 500 tons of coke is used per day, giving 140,000 cub. ft. of gas per ton, having a calorific value of 120 B.T.U. per cubic foot, 1,000 cub. ft. of this gas would give about 12 b.h.p. hours (8·5 kw.) in a gas engine, or evaporate 90lbs. of water in a Bonecourt boiler; this would give about 8½ b.h.p. hours or 6 kw. in a large turbine set. About 45 per cent. of the gas would be used for the stoves and 15 per cent. for gas or turbine blowing engines; this would leave 1,170,000 cub. ft. per hour, capable of producing

7,000 kw. in steam turbine generators, or
9,900 kw. in gas-engine-driven generators.

The very much higher capital cost, running and repair charges of the gas engines more than balance the higher thermodynamic economy. The cost per kilowatt is considerably lower in the case of a steam station, though the power obtained from the gas is less. With ordinary gas-fired boilers the steam per 1,000 cub. ft. of gas is usually not more than 50lbs., but improvements are now being made in gas burners for ordinary boilers, increasing the output to 75lbs. to 80lbs. per 1,000 cub. ft. of gas. The Bonecourt system is also being tried in ordinary Lancashire boiler furnaces, and evaporations of 85lbs. to 90lbs. per 1,000 cub. ft. of gas are expected.

If steam engines are used for driving the mills, steam generated by blastfurnace gas is not available, as gas or steam cannot be economically transmitted through the distances which must separate the blastfurnace and rolling mill plants. The usual practice is to generate steam from the waste heat from the smelting and heating furnaces, supplemented by hand firing or preferably by gas firing in the boilers, the gas being obtained from by-product gas producers. When electric power produced from blastfurnace or coke-oven gas is not available, steam produced in this manner may be used in a turbine driving the Ward-Leonard motor generator set supplying reversing rolling mills. The economical speed of steam turbines is very much higher than it is advisible to run direct-current generators dealing with such rapidly fluctuating loads as those due to reversing rolling mills; gearing would therefore be introduced between the turbine and the Ward-Leonard generator, allowing both machines to run at their most economical speeds. A flywheel would be coupled to the generator, and the turbine governor would be designed to give the necessary speed drop for utilisation of the flywheel energy. In this way the high steam economy and reliability of the steam turbine would be combined with the advantages of the electric motor for reversing mill drives, and the cost of motor-generator saved. The efficiency of high-speed gearing of the double helical machine-cut type is stated to be 97 to 98 per cent.; this compares favourably with the combined efficiency of turbine-driven alternator, 93 to 94 per cent., and induction motor with slip regulator, 90 to 93 per cent., that is, 84 to 87 per cent. overall. The steam consumption per ton of steel rolled would be correspondingly reduced. The capital cost of a reversing rolling mill equipment similar to that previously specified, but including two 1,200 h.p. steam turbines, with gearing and condensing plant instead of the induction motors, would be £33,000; that is somewhat higher than the induction motor-driven equipments, but against this must be set the higher economy and the fact that no generating plant is required for the mill drives.

Geared steam turbines are in use driving continuous-running mills. A 28in. plate mill in Scotland is equipped with a mixed pressure steam turbine running at 2,000 revs. per minute. The rolls run at 70 revs. per minute and a set of double-reduction gearing is used. The turbine is not running at its most economical speed, and the overall efficiency is probably lower than that of a higher speed turbo-alternator and induction motor combination. Geared turbines would be unsuitable for reversing mills owing to the high inertia of the rotating parts.

The examples given show that the electric motor, owing to its high and uniform starting torque, high overload capacity, reliability, and small size and weight, compared with other engines, is particularly adapted to reversing or intermittent loads. In some cases electric equipments are

slightly higher in first cost than plain steam equipments, but whereas electric power can be purchased or produced at less than ·35d. a unit, and in many cases up to 1d. per unit, reduced running costs can be proved.

In every case where the electric motor drive for rolling mills or winding engines has been installed, an increase in output over steam engines of similar capacity has been obtained. The numerous safeguards against overload or abuse which can be introduced into electrical equipments, have proved of such value that no serious breakdown of electric motors in this service has been recorded.

SOME RECENT DEVELOPMENTS IN COMMERCIAL MOTOR VEHICLES.

AT a meeting of the Institution of Civil Engineers, held on March 24th, a paper on this subject was read by Mr. Thomas Clarkson, M.Inst.C.E. During the period which had elapsed since the subject of motor vehicles was last reviewed before the Institution, remarkable developments had, he said, taken place in this department of engineering, both in regard to the quality of the vehicles and in the magnitude of their operations for the transport of passengers and merchandise. The period under review had witnessed the evolution of the motor-omnibus as it exists to-day. Greater facilities for the transport of passengers in cities were constantly in demand. Electric rail-motors, both on the surface and underground, had met this demand to some extent; but the motor-'bus had already demonstrated its superiority over the rail-car or tram. Complete flexibility was obviously impossible in motors dependent upon an extraneous power station; the vehicles must be self-contained, and the power generated from within. The author regarded flexibility as the key to the successful solution of the street traffic problem in cities.

The author referred to some typical examples of the commercial motors of the present day, and considered the suitability of various types of motor to the diverse conditions of industrial transport. There were at present three methods of generating power for commercial motor transport; namely, by internal-combustion engines, by steam engines, and by electric motors. Each of these methods had found a fairly clearly-defined field of utility. The internal-combustion motor far outnumbered the other types of motor for net loads up to three tons. For heavier duty than this, the steam motor continued to hold the field. The rise in the price of petrol had directed attention to other liquid fuels for the internal-combustion motor, and the steam-motor using solid fuel was being adapted for loads less than three tons, with the object of checking the ever-growing demand for motor spirit. The electric vehicle supplied with energy by a storage battery had made remarkably little progress in England.

The petrol motor was, he observed, confined to the employment of a volatile liquid fuel. The steam motor could use either liquid or solid fuels. The relative cost of the two systems for fuel per mile was governed by the ratio between the cost per pound of fuel and the mileage per pound. The fuel cost for a 3-ton petrol commercial vehicle, with petrol at 1s. 4d. per gallon, and at 8 miles per gallon, worked out at 2d. per car mile. The London petrol 'bus, which might be taken as equivalent to the 3-ton commercial vehicle, costs about 1d. per car mile for fuel. This lower fuel cost, it was explained, was not due to superior engine efficiency, but was the result of an exceptionally favourable contract for the purchase of petrol in very large quantities. The present cost of fuel for London petrol 'buses was, therefore, abnormal from the point of view of the ordinary user of petrol commercial vehicles. The steam omnibus at present costs for liquid fuel 1·875d. per mile, which was a little less than the cost of the ordinary petrol 3-ton vehicle. The steam omnibus, or 3-ton lorry, using coke, costs for fuel 0·4d. per mile with coke at 19s. per ton. The significance of this economy, and the real value of an apparently small reduction in cost per mile, was indicated by the fact that ½d. per mile represented, approximately, £200,000 per annum on the cost of running London omnibuses.

With regard to the relative reliability of petrol and steam cars, it had been demonstrated conclusively that with either type of motor the mileage lost from mechanical causes was extremely small, even when performing a commercial duty involving an annual mileage of 30,000 miles and more per vehicle. As regards the cost of mechanical upkeep, there did not appear to be any reason for a material difference between the two systems under this heading when they were run under similar conditions of management. The light steam 3-ton vehicle using coke as fuel might be regarded as combining the speed and handiness of the petrol motor, with a fuel cost equivalent to petrol at 4d. per gallon.

The author gave details of the construction of present types of both steam and petrol omnibuses, and dealt particularly with modern methods of omnibus illumination The important question of the construction of road wheels, most suitable for commercial motors of from 30 cwt. to 3 tons capacity, was dealt with. The present position of the electric commercial vehicle was considered in relation to other types of motor, particularly with reference to the investigations of working costs which had been recently conducted by the Massachusetts Institute of Technology. The author concluded with a reference to modern steam motor-wagons and tractors.

INDUSTRIAL AND TRADE NOTES.

A Costly Strike.—The settlement of the Cynon Colliery strike mark the termination of a costly and almost futile dispute. The men, numbering nearly 1,600, came out last April, demanding the payment of a farthing per inch for cutting clay in a certain coal seam. The company made a counter offer, which was refused. The strike that followed has cost the men over £40,000 in wages alone, and involved a heavy loss to their federation. The terms now arrived at represent only a slight modification of the company's original counter offer.

Gas Undertakings in the United Kingdom.—A Parliamentary return relating to gas undertakings in the United Kingdom in 1912 gives the number of authorised undertakings as 826, of which 520 belonged to companies and 306 to local authorities. The authorised capital and loans amounted to £161,253,541 and the amount paid up and borrowed was £137,461,970. During the year 215,492 million cubic feet of gas were made in the United Kingdom and 198,922 million were sold. Gas mains totalled 37,744 miles, and there were 735,121 public lamps. The number of gas consumers was 6,876,149, compared with 6,649,904 in the previous year.

Trade Catalogues. We have received the following trade publications: From the Anglo-American Petroleum Products Co., Finsbury Pavement, London, E.C., a bound volume of 150 pp., giving an account of the oil resources of Mexico, with descriptions of mechanical appliances for the burning of oil with data of its relative calorific value as compared with coal. From the Dudbridge Iron Works, Ltd., Stroud, a copy of a new edition of their catalogue on gas engines and suction gas plants. From the Parsons Motor Company, Ltd., Southampton, copies of their catalogues of marine and stationary petrol and paraffin engines, and also of marine craft fitted with their special types of engines.

The Steel Trade Combine.—At the conference of English and Scotch steelmakers, representing the British combine, held at Newcastle, on Friday last, it was arranged to make certain modifications in prices as regards Scottish members. For several months back the trade has been seriously affected by heavy importations of plates and angles, which were secured at lower quotations than obtained in the home market. As a result much of the rolling plant in the Clyde district has been thrown idle. It was soon realised, that if conditions were not to become worse continental competition must be actively faced, and the only method available was a reduction of prices. It has been agreed that Scotch steel producers are to have a free hand in the matter of selling boiler and ship plates, angles, and sections in the Scottish area, and in the export markets, but are not at liberty to cross the border and sell, unless on the same basis as is recognised by English makers, plus the cost of carriage to the buyers.

A New Electrical Trades Association. At a meeting held a few days ago in London, it was decided to form an "Association of Managers, Supervising Engineers, and Permanent Foremen attached to the Electrical Contracting Trades." The objects of the Association are: (*a*) To assist members in obtaining information of situations. (*b*) To form a technical library for the use of members. (*c*) To form a benevolent fund for the assistance of members in distress. (*d*) To endeavour, by means of lectures and visits to large works, to maintain a high standard of efficiency of all members. (*e*) To foster the apprentice system for learners in

the electrical trade. (*f*) To endeavour to extend the attendance of electrical workers at evening schools, both technical and practical. (*g*) To arrange for the reading of papers on electrical subjects by members or visitors invited from other societies. (*h*) To arrange periodical social gatherings to promote knowledge and good fellowship amongst members. Full particulars regarding membership may be obtained from the hon. secretary, Mr. C. J. Banister, 14, Pulborough Road, Southfields, S.W.

Dimensions of Large Liners.—In the latest Supplement to Lloyd's Register Book the new triple-screw White Star liner "Britannic," launched last month by Messrs. Harland & Wolff, of Belfast, is returned as of the following dimensions: Length, 852ft. 5in.; breadth, 94ft.; depth, 59ft. 5in.; and measurement, 47,500 tons gross, 35,650 tons under deck, and 24,000 tons net. It may be recalled that the dimensions of the new Cunard liner "Aquitania," as published at the time of the launch, were: Length, 901ft.; breadth, 97ft.; depth to boat deck, 92ft. 6in.; and measurement 47,000 tons. The Board of Trade figures for the "Aquitania," however, are not yet available, so that the dimensions of the two vessels cannot be authoritatively compared. The latest official figures for the Norddeutscher Lloyd liner "Imperator" are: Length, 883ft. 6in.; breadth, 98ft. 3in.; depth, 57ft. 1in.; and measurement, 52,117 tons. The only official figures available for the second large Norddeutscher Lloyd liner, the "Vaterland," are those showing the measurement, which is given as 56,000 tons.

Alcohol as Motor Fuel.—The Alcohol Motor Fuel Committee of the Imperial Motor Transport Council have issued a preliminary report in which they express the opinion that alcohol affords the only possible escape from the difficulties in the present position. In this connection, and in view of the importance of rendering the British Empire independent of fuel supplies from foreign countries, it should be noted that crops from which alcohol can be obtained might be cultivated with great benefit to the agricultural community in many parts of the Empire. In the great majority of the Dominions and Colonies, alcohol offers the only feasible relief from abnormally high prices and shortage of supplies. Denaturing, they say, is possibly one of the most important aspects of the whole subject, and it is desirable to obtain all the information available on the question. Ultimately, the question of denaturants will have to be discussed with the Government authorities of this country, and with the Governments of the various constituents of the Empire overseas, with a view to a mutual agreement as to the smallest quantity of the cheapest and most satisfactory denaturant which these Governments will allow in a fuel alcohol to be sold on the open market.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester

MECHANICAL, 1912.

Elastic-fluid engines. Thorne. 23497.

1913.

Propulsion of vessels. Round. 2273.
Steam generators. Field. 2458.
Variable speed gearing. Horsley and Daimler Company. 2479.
Air compressors. Reavell & Co., Reavell & Jones. 2754.
Furnace fire bridges. Cooper. 2979.
Transmission gear or clutches. Leitner & Kingsland. 3423.
Speed indicators. Varley. 5144.
Change speed gears. Holliday. 5151.
Hydraulic pumps. Rodhe. 5153.
Multi cylinder internal combustion engines. Nyborg. 5229.
Steam-flow meters. British Thomson Houston Company. 5306.
Vaporisers for internal-combustion engines. Roberts. 5315.
Valve gear of internal-combustion engines. Stanbridge. 5403.
Rotary motors. Peterson. 5462.
Internal-combustion engines. Scharf. 5555.
Utilisation of steam in steam turbines. Parsons. 5906.
Internal-combustion engines. Junkers. 5941.
Rocking furnace bars. Halstead. 6203.
Milling cutters. R. Stock & Co. 6571.
Central exhaust steam engines. Smal. 6577.
Machines for coiling spiral springs. Wagner & Ficker. 7467.
Internal-combustion engines. Allgemeine Electricitats Ges. 9257.
Revolving cylinder fluid-pressure motors. Sellers. 9537.
Apparatus for washing or scrubbing gas. Williams. 10066.
Preventing formation of CO in cupola furnaces. Schurmann. 11073.
Prevention of incrustation in boilers. Radaeff. 11354.
Motive-fluid generators. Smith. 11995.
Internal-combustion engines. Penning. 12068.
Carburetters of internal-combustion engines. Thomas. 12416.
Packing devices for centrifugal pumps. British Thomson Houston Company, and Collingham. 12838.
Gas-producers. Jolly. 13737.
Melting-pot furnaces. Coppée. 14726.
Curved teeth for gear wheels. Bottcher. 15278.
Adjustable cutter for boring bars. Pattinson. 16162.
Locomotive steam exhaust nozzles. Hayward & Sanderson. 16856.
Automatic coupling for railway vehicles. Rossetto. 17798.
Carburetters for heavy oils. Dignef. 18021.
Gas generators. De Fontaine. 18413.
Valve mechanism for gas engines. Ray & Carter. 19545.
Centrifugal pumps. Eisenwerk Akt-Ges., and Schneider. 20580.
Expanding pulleys. Decoux. 20794.
Railway rail joints. Corbin. 20911.
Metal melting furnaces. Hall. 21158
Pipe couplings. Viola. 22058.
Nut-locking devices. Holman & Holman. 24368.
Belt shifter. Mackay. 25352.
Carburetters. Furness Williams. 25758.
Piston packing rings. Warren. 26159.
Carburetters for internal-combustion engines. Hamill. 26431.
Controlling device for internal combustion engines. Kruse. 27016.
Lubrication of crank gearing. Otten. 27033.
Internal-combustion engines. Atwood. 27161.
Pressure reducing valves. Graham & Graham. 27903.
Band-sawing machines. T. Robinson & Son, Ltd. 27990.
Valves. Cockburn & MacNicoll. 28482.
Purifying "producer" gas. Wallwin & Sinnatt. 28682.
Annealing vessels. Romer. 29393.
Means for charging and discharging furnaces. Ferman, and Ferman & Co. 29666.

1914.

Vaporisers for internal-combustion engines. Roberts. 1235.
Means for preventing the creeping of railway rails. Bodkin. 2631.

ELECTRICAL, 1912.

Electric welding. Jones. 27496.
Electric storage batteries. Davies. 28086.
Regulation of dynamos. British Thomson Houston Company. 30107.

1913.

Telephone systems. Siemens Brothers & Co. 2409.
Automatic wireless train control apparatus. Clark. 4901.
Impulse transmitting devices. Automatic Telephone Co. 5249.
Electrically controlling railway switches. Alexander. 5295.
Telephone exchange systems. Western Electric Company. 5654.
Electric motor controllers. Morrison. 5792.
Telegraphic transmitters. Steljes & Rebesi, Ltd. 5805.
Motor control-systems. Crompton & Co., and Burge. 6806.
Electric cables. Smith & Garnett. 7311.
Electrical indicating apparatus for use on steam trains. White and Gardener. 8273.
Electric transformers. Brain & Leech. 8591.
Automatic systems of train control. Siemens Bros. Dynamo Works, Ltd., and Duke. 8624.
Electric switch. Allgemeine Elektricitats Ges. 10077.
Electric lamps. Hitzelberger, and New British Ever Ready Company. 14423.
Supplying fuel to internal-combustion engines. Steinbecker. 17298.
Power-control system for automatic switches. Western Electric Company. 20591.

METAL QUOTATIONS.

TUESDAY, MARCH 24TH.

Aluminium ingot	86/- per cwt.
,, wire, according to sizes, &c. ......from	112/- ,,
,, sheets ,, ,, ... ,,	112/- ,,
Antimony	£27/10/- to £29/10/- per ton
Brass, rolled	7¼d. per lb.
,, tubes (brazed)	9⅝d. ,,
,, ,, (solid drawn)	7⅞d. ,,
,, ,, wire	7⅜d. ,,
Copper, Standard	£65/5/- per ton.
Iron, Cleveland	50/9 ,,
,, Scotch	56/9 ,,
Lead, English	£19/15/- ,,
,, Foreign (soft)	£19/10/- ,,
Mica (in original cases), small	6d. to 3/- per lb.
,, ,, ,, medium	3/6 to 6/- ,,
,, ,, ,, large	7/6 to 11/- ,,
Quicksilver	£7/10/- per bottle
Silver	26 13/16d. per oz.
Spelter	£21/10/- per ton.
Tin, block	£176/5/- ,,
Tin plates, I.C.	13/- per box.
Zinc sheets (Silesian)	£24/15/- per ton.
,, (Stettin; Vieille Montagne)	£25/2/6 ,,

The Mechanical Engineer.
An Illustrated Weekly Journal
Vol. 33, No. 845.

Edited by
WILLIAM H. FOWLER,
Wh. Sc., M.Inst.C.E.

Telegrams: "Scientific," Manchester.
Telephone No. 6055 City.

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Advertisements, displayed, for insertion in current issue should reach our Manchester office not later than first post Tuesday morning, and small prepaid advertisements not later than first post Wednesday morning.

Profit Sharing and Co-partnership.

An interesting report on profit sharing and labour co-partnership abroad has been issued by the Labour Department of the Board of Trade. It is in continuation of one issued about 18 months ago on similar schemes in the United Kingdom.* That report did not encourage the belief that any extensions of them would provide a panacea for the labour troubles that appear to be more or less a concomitant of periods of trade prosperity, and which have been so particularly pronounced during the last few years. In our comments on that report we pointed out what appeared to us to be the reasons for this, and nothing that has since transpired has led us to modify the views we then expressed. Advocates of profit sharing and copartnership appear to overlook some fundamental considerations in the relations between capital and labour. For instance, profits do not always accrue. On the contrary losses often melt all the capital away. Again, in the early days of an enterprise it is difficult to say what the result will be, and contingent profits are too vague to induce any workman to fetter an ordinary wage contract which he can break at leisure. At any rate it is the one on which he prefers to rest his relations with his employer, and it certainly leaves him freer to "down tools" and break the agreements of his trade union, which is immune from any action for wrong, than would be the case if he became directly associated with his employers' risks. It may be said that, notwithstanding this criticism, a number of profit sharing and copartnership schemes have worked, and do work, satisfactorily in the United Kingdom, but, compared with industry as a whole, they are an insignificant number, while a review of the statistics presented, as far as the engineering and allied industries are concerned, is particularly discouraging. The analysis furnished by the Board of Trade showed that out of six mining and quarrying schemes that had been instituted all

* See our issue of December 13th, 1912, p. 729, Vol. XXX.

had been abandoned when the figures were compiled. In the metal trades, of nine that had been started only one survived, while out of 21 concerned with engineering and shipbuilding, there were only four. The only manufactures in which schemes of this kind seem to endure are those in which a monopoly is more or less enjoyed, and in which profits are assured, such, for example, as gas works, where out of 34 schemes originally initiated only one had been abandoned. The manufacture of gas cannot, however, be taken as one presenting the risks and anxieties associated with the making of profits in the majority of industries, and which it seems to us must always be a serious barrier to any schemes which seek to combine the temporary interests of the workman as a wage earner, with the interest of a capitalist. Capital is not, as many workmen think, outside their reach or confined to a few. The great majority of enterprises are collectively owned, and it is possible for even the smallest capitalists to participate. There is nothing to prevent a workman investing his savings and participating in the profits of the millionaire, nor is there anything to prevent a body of working men running any manufacture they choose just as freely as they run a trade union. If some of those who talk so much of the tyranny of capital and the helplessness of labour were to do this they would find that the boot is oftener on the other leg. The fact is manufacturing enterprise, to be successful, entails serious anxieties and responsibilities, and depends more on the qualities of the organisers than on money. Such men are workers as truly as the humblest toilers in the ranks. Nay, their toil is usually more strenuous and is only secured by high rates of pay that leave only a small margin of profit to capital, and often not that. If such men happen to be employers their profits are largely in the nature of a wage which their services would command in the labour market like any other worker. A man is not necessarily less of a worker because he is an employer or even a capitalist. Though, according to the doctrines of some "labour leaders," if a man has, by working harder and longer, by exercising greater thrift and self-denial than his fellows, accumulated capital and become, it may be, an employer, he is then fit only to be dubbed "thief" or "tyrant."

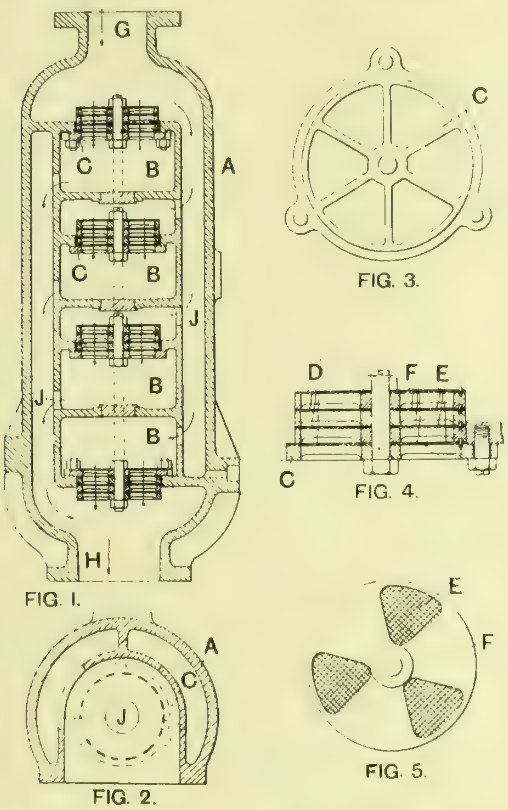
The voluminous report presented by the Board of Trade on the working of profit sharing and labour co-partnership in continental countries and the United States do not modify the conclusions derived from those that have been tried in this country. The schemes have only been few in point of numbers, while many have been abandoned. France is the country in which schemes of this kind have been longest in existence, in fact, the oldest profit-sharing scheme was started by the National Fire Insurance Company of Paris in 1820, or 45 years earlier than anything of the kind was instituted in this country, and insurance companies furnish the largest group of businesses in which arrangements of this kind exist there to-day. Whilst organising ability is doubtless called for in the management of such concerns, it cannot be contended that they present the complex questions that arise between capital and labour in the engineering trades, where skill and organisation count for so much. In Germany, the report states, "profit-sharing has made little progress, and many of the schemes introduced have been comparatively short-lived. Thus of 54 schemes recorded in 1878, only nine remained in existence in the summer of 1901, while at the present moment only about 30 schemes in all are known to be in existence, while the 21 undertakings for which particulars are available only employ about 15,000 persons." In Holland, Switzerland, and Italy profit-sharing schemes are even rarer than in Germany. In the United States, notwithstanding its enormous area and infinite industries, only about 25 or 30 firms are reported as having introduced schemes of this kind, though some of the firms who have done so are very large. The two most conspicuous are the United States Steel Corporation and the United States Rubber Company, but here again the firms possess, more or less, monopolies of trade, and to a great extent are immune from the risks associated with ordinary enterprises. The report states that, "on the whole, profit sharing is not regarded with very great favour in the United States, either by manufacturers and business men, or by economists, the reasons given being: (1) The attitude of the trade unions, and (2) the preference of employers for other means of improving the position of their workpeople, such as welfare institutions, in the shape of sick, accident, and pension funds, athletic and social clubs, reading rooms, &c." As regards the British Dominions, the progress of profit sharing has made even less progress than elsewhere, and curious to relate, in Australia and New Zealand, where legislation is exceedingly favourable to labour, it has, according to the report, scarcely obtained any foothold, while the same may be said of South Africa and Canada. A general survey of these schemes, in fact, offers little hope of relieving society from the labour trouble in which it is periodically involved, and which appears to be getting chronic The wider adoption of the principle of arbitration would seem to offer a better avenue for relief, but for progress of any kind there must be a more general recognition by the members of trade unions of the sacredness of contracts in collective bargaining, and before this is attained much teaching will be required, and also, we fear, in the lower ranks of labour much painful experience.

PREVENTING CORROSION IN STEAM TURBINES.

It is well known that steam has a corrosive action upon the castings, rotors, and blades of steam turbines, especially in the case of marine installations. It is found that such corrosive action is almost entirely due to salt, principally in the form of chlorides of sodium and magnesium coming over with the steam from the boilers, as sometimes happens when salt is allowed to get into the boilers through leaky condensers or in some other way. The corrosion arises from a chemical action on the part of the salts between the steel or cast iron of the bodies of the rotor or casing respectively, and the brass or copper of the working blades and dummy strips. It is also found that this corrosion is practically limited, at any rate to any serious extent, to the first few rows of blades and dummy strips with which the fresh steam comes into contact. To enable this corrosive action to be avoided the Hon. Charles A. Parsons, Heaton Works, Newcastle-on-Tyne, proposes in a recent patent to render the steam before admission to the turbine substantially chemically inactive as regards the metal parts of the turbine. The invention also consists in a strainer through which the steam passes before entering the turbine, the steam in passing through the strainer coming into contact with metals similar to or not less active than those of the turbine parts, so that the corrosive action of the steam is expended in the strainer.

Fig. 1 is a sectional front elevation through the strainer. Fig. 2 is a sectional plan. Fig. 3 is a view of one of the plates C seen from below. Fig. 4 is an enlarged sectional view of one of the groups of perforated plates and baffles. Fig. 5 is a plan of Fig. 4. The strainer A is, as usual, placed in the conduit by which the steam is conveyed to the turbine, and consists in a number of compartments B through which

the steam passes in parallel. The steam enters at G and leaves at H, following the course indicated by the arrows, the compartments being provided with apertures J for passage of the steam. In each compartment are provided perforated partitions C upon which are mounted alternate plates of brass D and steel E, these plates being perforated. The effective area of these perforated plates is controlled by one or more baffles F. A removable cover is provided at the side of the strainer A. It will be seen therefore that the steam in passing through each compartment of the strainer comes into contact with alternate plates made of the same metals as the parts of the turbine. The corrosive action of the steam on these metals therefore takes place in the strainer, and the salts in the steam producing the corrosion are killed before they reach the parts of the turbine. In this way the steam is rendered chemically inactive upon the parts of the turbine before it is admitted thereto. The steam is preferably passed through the perforated plates of brass and steel D and E in the strainer at a comparatively high velocity, and the area through the perforation of these plates



STRAINER FOR PREVENTING CORROSION IN STEAM TURBINES.

made small enough to ensure a small pressure drop, for instance, of 3lbs. to 5lbs. per square inch between the pressure of the steam at the inlet to and the outlet from the strainer. It is found that the extraction of a certain amount of the intrinsic energy from the steam in this manner promotes the chemical action of the steam upon the perforated brass and steel plates D and E and ensures the effectiveness of the strainer in rendering the steam chemically inactive. The mechanical construction of the strainer is such that the perforated brass and steel plates can be readily removed and replaced.

It will be seen that by this arrangement the detrimental corrosive action of the steam upon the metal of which the turbine parts are formed is transferred from the turbine parts themselves to a strainer where the products of the corrosion can be easily removed and the parts attacked readily renewed as often as required.

Trials for Agricultural Tractors.—The Royal Agricultural Society propose to hold in the autumn of 1915 trials for agricultural tractors and for ploughs to be used with tractors. A sub-committee has been appointed to draw up the necessary regulations.

LIFE OF CUPOLA LININGS.

THE following record of a cupola lining, given by Mr. W. A. Griswold in a paper recently read before the American Foundrymen's Association, will be of interest to foundrymen, as an instance of the length of life attainable when the bricks are given proper treatment. It was, he said, well known that even with the best qualities of firebricks for cupola linings, poor results were obtained when the bricks were laid with inferior clays for a mortar. The more readily fusible clay thus introduced between the best of bricks would start a slagging action within the range of the melting zone, and the result was a more or less rapid washing away of the lining. If, coupled to this, the daubing was also prepared with clays high in fluxing ingredients, such as lime, oxide of iron, alkalies, &c., the result would be a necessary relining of the melting zone at very frequent intervals.

In the case referred to, the firebricks were laid without any clay mortar whatever. They were placed to within ¾in. of the shell, and the space thus left filled with parting sand. Care was taken to have the joints as small as could be made. Charging the cupola was carried on with the ordinary care that should be given this work. The blast pressure ran from 12oz. to 15oz., the melting rate was from 14½ to 16 tons per hour, the cupola diameter inside the lining 66in., and the melting ratio from 8·1lbs. to 8·4lbs. iron per pound of coke. From the above figures it will be seen that full returns were expected from the cupola, and the lining was not "nursed" by any means. The lining was put in June 2nd, 1912, and no new bricks were put in until the cupola was again relined October 19th, 1913, it being deemed inadvisable to take any chances. After the lining was out, however, it was seen that the cupola could have been run for another 100 heats safely. As the castings to be made were all of the lightest character, consisting entirely of stove plate and hollow-ware, very hot iron was required. This condition was accentuated by the fact that after tapping into bull ladles, holding about a ton each, the metal was carried to the different sections of the moulding-room, poured into hand ladles, and then into the moulds. The total melt during the period in question was 12,775 tons, which gave an average of 29·8 tons per day.

Where foundrymen had to reline the melting zone frequently, not to speak of the rest of the cupola lining, a little attention to the work in the first place, the exclusion of materials allowing fluxing action between the bricks themselves, careful chipping to remove slag that would continue to eat in further with every melt, and at the same time allow any daubing put on to slip off the moment the slag behind became soft, would result in maintaining the integrity of the lining for a surprising tonnage and length of time.

Fatal Explosion of a Benzol Drum.—A violent explosion occurred at the works of Messrs. Robert Wilson & Sons, Ltd., engineers, Bishop Auckland, on March 18th, resulting in the death of one man and injury to another. It appears that the men were engaged at the time of the explosion in welding a crack in a benzol drum, and for this purpose were using an oxy-acetylene welder. As a result of the explosion the top of the drum was blown off, and the flying metal caught deceased. At the inquest it was stated the drum was cleaned by rolling it up and down the yard. Steaming is the usual method of cleaning these drums, but it was admitted that this was not carried out.

The Junior Institution of Engineers: North-western Section.—A meeting of this Section was held on March 26th, at which Mr. T. R. Wollaston, M.I.M.E., opened a discussion on "The Power Driving of Small Workshops." Plant requiring 20 h.p. was taken as the basis of discussion. The claims of steam, petrol, oil, and gas engines were considered, and a comparison of the latter type, using town's gas and producer gas, was made. All these methods were shown to compare unfavourably with electric motors, driven by current purchased from a generating station. Economies in space and cost of current on light loads, absence of noise, smell, and vibration, also ease in transmission of power to different parts of the building, were some of the advantages pointed out.

DIESEL ENGINE DESIGN.

IN the course of the discussion on the paper on "The Present Position of the Diesel Engine, Chiefly in Marine Propulsion," read by Mr. George Carels, before the North-east Coast Institution of Engineers and Shipbuilders, on November 28th last, and reproduced in our issues of December 12th and 19th (see pp. 549 and 579, Vol. XXXII.), Mr. W. R. Cummins referred to some of the faults in existing designs of Diesel engines and gave particulars of a proposed design to overcome them. His remarks, reproduced from the March issue of the transactions of the Institution, are as follows:—

Mr. W. R. Cummins explained that the weak points of the marine Diesel engine as at present constructed, were the barrel or liner, the cylinder cover, and the piston—in fact, those parts which were exposed to high pressures and temperatures. This applied to both the 4-stroke and the 2-stroke engine, but perhaps in a greater degree in the latter owing to the increased output demanded of the same size of cylinder. He had prepared diagrammatic sections of the upper part of the cylinder and piston of several types of Marine Diesel engines, but before considering any of these he thought it would be well to set forth the conditions to be observed in order to deal successfully with the temperatures and pressures experienced.

In the first place, the surface exposed to burning fuel should be as large as practicable and cooled in the most efficient manner. This might entail a small sacrifice of

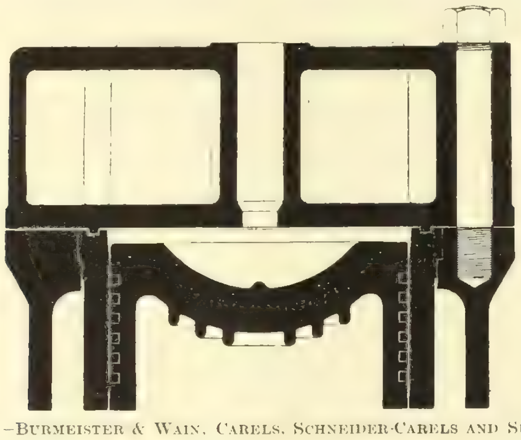


FIG. 1.—BURMEISTER & WAIN, CARELS, SCHNEIDER-CARELS AND SULZER.

thermal efficiency but nevertheless was absolutely necessary if reliability was to be secured. The problem of cooling became more difficult as the diameter of cylinder increased, because the amount of heat carried away varied with the cylinder volume, although the surface did not increase in the same ratio as the volume. The adoption of the 2-stroke principle also increased the difficulties.

The working barrel or liner should be of exceedingly hard close-grained material to enable it to stand the wear of the piston rings, which up to the present had always been of Ramsbottom type. Such piston rings allowed the gas to get behind them and press them outwards against the cylinder walls, thus causing great wear unless the liner was very hard. The barrel or liner should also be as thin as practicable, and of high thermal conductivity to enable the greatest possible amount of heat to be transmitted to the cooling water. This restriction as to thickness, in order to maintain a reasonable thermal gradient, necessitated the material being of great tensile strength to enable the barrel to meet the heavy bursting pressure it had to withstand. In addition, the barrel should be free to expand both longitudinally and radially, and there should be no ribs to prevent this or to cause distortion.

The cylinder cover, or head, should be of high thermal conductivity, with the maximum of surface exposed to the direct influence of the cooling water. If a separate cover be used, the making of the joint should not impose on the cover, or its studs, any stress in excess of that produced by the pressure in the cylinder. Finally, the piston should be of high conductivity material, of perfectly symmetrical form and uniform thickness. The fuel valve should be placed as far above the piston as possible, to protect the crown of the piston from the blast of the burning fuel.

The only material which appeared to stand up against the high temperatures and the friction of the piston rings was a cast-iron mixture; but it was unfortunate that cast iron had a relatively low heat conductivity, and not a naturally high tensile strength. Again, cast iron was not naturally adapted to withstand fatigue, a type of stress which had to be expected owing to the marine engine having no regular periods of rest.

Having enumerated these conditions, Mr. Cummins wished to examine the various designs of Diesel engines in order to see how they were fulfilled. Taking the Burmeister & Wain 4-stroke design (Fig. 1), it would be seen that the cast-iron liner was dropped into the water jacket and held down at its top end by the cylinder cover. The bottom end of the liner was free, and was able, therefore, to expand longitudinally when heated up. It would be apparent that the material used for these liners must have a high tensile strength. Taking the thickness as given in the published drawings, the stress due to 750lbs. per square inch in the cylinder worked out to about 4,200lbs. per square inch; a factor of safety of 6 would require a tensile strength of 11 tons as against 8—8½ tons, which was the strength of cast iron generally used for steam engine liners. Metallurgists had, however, been able to produce material of 15 tons tensile strength at ordinary temperatures, and it would be interesting to know what reduction of strength occurred under actual working conditions. With such high tensile strength must be associated great hardness usually inseparable from brittleness and inability to withstand fatigue.

The next point to observe was the heavy flange at the top of the liner, and the ineffective cooling at that point. The heavy flange might help to increase the strength of the liner, but it must prevent free radial expansion, and thus set up non-calculable stresses. The cover contained five valves, and the space occupied by them did not leave much room for water-cooled surface. Also the cold air inlet at one side of the cover, and the hot exhaust outlet at the other, must cause unknown temperature stresses. The cover joint was made by a spigot in a recess in the liner flange. In hardening up this joint, the cover and studs had a heavy stress put on them, which was additional to that produced by the pressure in the cylinder. The piston head, it would be noticed, was very thick, as the cooling was by oil (which was comparatively ineffective), radiating ribs being cast internally on the crown, to help matters. The piston was dished downwards in the centre to protect it as much as possible from the fuel blast. In spite of this the fuel valve did not appear to be sufficiently far away from the piston, or the latter would not need to be so thick.

The same diagram (Fig. 1) would serve to illustrate the Carels design, and the same remarks applied to the liner, but it must be remembered that, being a 2-stroke engine, the liner must transmit a very much larger amount of heat than that of the 4-stroke. The Carels cylinder cover had seven valves, and therefore very little water cooled surface was available. The piston was much more deeply dished than the Burmeister & Wain type, and was cooled by water.

The Sulzer design might also be illustrated by Fig. 1 diagram. It, however, had port scavenging, and therefore only three valves in the cylinder cover, which consequently could be more effectively cooled than the other types.

Turning next to the Werkspoor design (Fig. 2.), it would be seen that the cylinder head and the barrel were of cast iron in one piece, which entailed not only drawing the piston from below, but also a great deal of additional expense, if the cylinder barrel had to be renewed. The importance of efficient cooling of the barrel, at the point of maximum temperature, had been recognised in this design, and in that respect was much superior to the Burmeister & Wain, Carels, and Sulzer types. Additional strength and cooling surface was given by a circumferential rib near the top of the barrel, which, however, would prevent free radial expansion, and be liable to cause sponginess in the cylinder bore. As there was no cover, there was no high pressure joint to make, but on the other hand, the radial ribs running from the barrel to the stud bosses would not allow of a free radial expansion, the result being that the barrel would want to bulge out between the ribs, and set up unknown stresses. There were five valves in the head, and these would occupy a large amount of surface, which could otherwise be devoted to water cooling. The piston was dished downwards to protect it from the fuel blast,

and was cooled by water. The design of the Krupp cylinder was very similar, and the same remarks applied to it.

Passing on to the Polar design (Fig. 3), the barrel was cast in one with the water-jacket, and to replace a worn barrel entailed an entirely new cylinder. The barrel and water jacket were joined together at the top by metal into which the cover studs were screwed. This did not allow free expansion of the barrel in a longitudinal direction. The top of the barrel also could not expand freely in a radial direction on account of these stud bosses. It would be noticed, however, that the water cooling at the top of the barrel was good, and nearly equal to that of the Werkspoor and Krupp. The cylinder cover contained only two small valves, owing to port scavenging, and had therefore ample water cooled surface. It was, however, of unsymmetrical shape, and therefore liable to contraction stresses. The piston also was of unsymmetrical

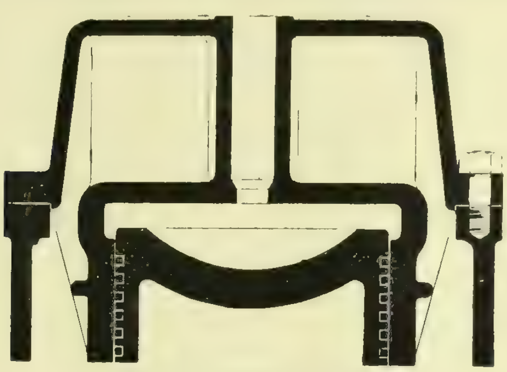


FIG. 2. -WERKSPOOR & KRUPP.

shape, due to the method of scavenging. In the larger sizes it was cooled by water.

The Reiherstieg (Fig. 4) was a modification of the Carels, and it would be seen that an attempt had been made to increase the efficiency of the water cooling at the top of the liner. The wide flange at the top, however, would effectually prevent radial expansion, and it was difficult to see how the metal would adjust itself when heated.

In the Junkers design (Fig. 5) the cylinder consisted of a plain barrel with exhaust ports at one end and scavenging ports at the other. There were no cylinder covers, properly speaking, their place being taken by two opposed pistons. At first sight this appeared to be an ideal design, as it was practically valveless, and the barrel could be efficiently cooled at the point of maximum temperatures. There were, however, three bosses cast on the barrel for the fuel, starting, and relief valves, and the presence of these bosses was certain to lead to trouble.

Now, looking at the various examples illustrated, and realising the severe conditions imposed, it seemed extraordinary that the Diesel engine should have already attained such a large measure of success in marine work. It seemed, at first sight, to be more a problem for the big gun maker, rather than the engine builder. Mr. Carels had quoted Prof. Junkers' figures for the amount of heat transmitted to the jacket water through the cylinder walls, viz., 260,000 calories per hour per square metre, equivalent to 95,000 B.T.U. per hour per square foot. This was presumably for the Junkers type of engine, and it would be interesting to roughly calculate the heat transmission for a Carels cylinder 20in. diam., 36in. stroke, developing 285 h.p. at 100 revs. and 100lbs. mean pressure. Taking the loss of heat through the jacket water to be 34 per cent. and exhaust loss 24 per cent. of the heat value of the fuel, the B.T.U. transmitted to the cooling water would be

$$285 \times \frac{34}{42} \times \frac{33{,}000 \times 60}{\cdot 772} = 590{,}000 \text{ B.T.U. per hour.}$$

It was probable that at least two-thirds of this heat, viz., 393,300 B.T.U., was given up during the constant pressure period. The surface available for transmission would be:—

Piston head	325
Cylinder cover ...	195
Liner	283
	803 sq. in. 5·6 sq. ft.

So that the mean rate of transmission was no less than 70,000 B.T.U. per hour per square foot, and the maximum considerably more. Now in a steam boiler the rate was only one sixth of this, and comparatively thin steel plates were used which had 20 per cent. better heat conductivity than cast iron, but in spite of this the unfortunate results of a mere film of oil on the heating surfaces were well known. Mr. Carels said it was entirely a matter of metallurgy, and certainly the highest credit was due to those who had achieved so much in such a short space of time. It seemed to Mr. Cummins, however, that the metallurgist could be helped a great deal by modifications in design.

Fig. 6 illustrated a design intended to fulfil a great many of the conditions laid down in the early part of his remarks. As would be seen, the top of the liner was perfectly free, and reinforced circumferentially by a number of steel rings shrunk on the outside, and separated from one another by a space which allowed the cooling water to have access right up to the cast iron, irrespective of its tensile strength, as the bursting stress was taken care of by the steel rings. The cast iron could be comparatively thin, and the combination formed a very efficient cooling arrangement. It would be noticed that the level of the cooling water in the jacket was well above the bottom of the cylinder cover. The top of the liner was connected to the water jacket by a flexible tinned copper disc, which allowed perfect freedom of expansion to the liner top, both longitudinally and radially. The difference in the coefficient of expansion of the cast-iron liner and the steel rings was compensated by their differing temperatures. The cast-iron liner expanded less per degree of heat than the steel rings, but the cast iron had a greater mean temperature than the steel rings.

The diagram showed the 2-stroke cycle design, and it would be noticed that the exhaust ports and the scavenging ports (the latter were not shown) were cast in one with the outer wall of the water jacket, so that each separate port was water jacketed all round and leakage from the jacket made impossible. Also, the difficulty of making a sliding watertight joint at the ports involving very delicate and accurate machining, as in the Carels and Sulzer design, was entirely eliminated. By removing the upper part of the outer wall of the jacket, the extension of the liner with its reinforcing rings, and the exterior of the exhaust ports, were perfectly accessible for scaling and cleaning. The cylinder cover had a central bung, projecting into the bore of the liner, and fitted with six spring rings. The joints of these rings were so cut that there was no straight flow through for the gas. There might be a slight leakage past them, but it would be much less than

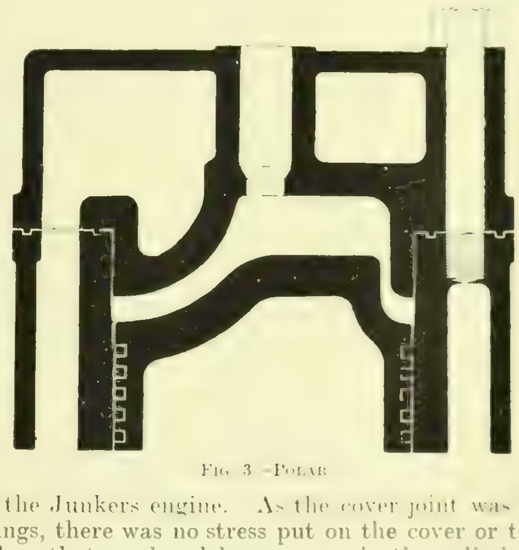


FIG. 3 -POLAR

that in the Junkers engine. As the cover joint was made by these rings, there was no stress put on the cover or the studs, other than that produced by pressure in the cylinder. The design as shown was intended for port scavenging, and only two valves, fuel and relief, were shown in the cover. The absence of the starting valve will be explained later. The fuel valve was placed at the top of a deep conical recess, so that the piston was well protected from the blast of the fuel, and could therefore be made much thinner in the crown than was usually the case. The conical recess also added to the water-cooled surface. The more heat there was taken away by the cover and liner, the less would remain for the piston to remove which would always be the most difficult part to cool effectually. Owing to the increased surface of the cover as shown, the rate of heat transmission for a cylinder of same

size and conditions as quoted above was 18 per cent. less. The design eliminated most of the difficulties which all present designs would experience in passing to the large diameter cylinder, and the metallurgist was relieved of the necessity of producing high tensile strength material.

Mr. Carels raised the point of 4-stroke *versus* 2-stroke, and valve scavenging *versus* port scavenging. It appeared to Mr. Cummins that simplicity and reliability demanded the 2-stroke port scavenging type. Valves opening inwards into a cylinder would not be tolerated for an instant on a marine steam engine, and they should not be tolerated on a marine Diesel. He had heard of no authentic cases of valves falling into the cylinder, but there was the possibility, and if such a thing happened it would cause an unpleasant smash. It was quite true that more perfect scavenging could be obtained by valves in the cover, but an imperfect scavenge did not decrease the thermal efficiency of the engine. This point was not made quite clear by Mr. Carels in his paper. An imperfect scavenge merely affected the I.H.P. obtainable from a given cylinder. With a cylinder full of pure air there was enough oxygen present to burn sufficient fuel to give a heavy overload, which was the very thing to be avoided in the marine Diesel in its present stage of development. A sudden increase in the amount of heat developed in the cylinder might quite overpower the inadequate cooling facilities and be the cause of the overheating and cracking which had done so much to retard progress. Port scavenging, by restricting the supply of oxygen, formed a natural safety device against overload. For instance, in a 2-stroke cylinder 20in. diam. and 36in. stroke, the horse-power per revolution at 100 revs. with 100lbs. mean pressure would be 285, and the fuel burned per hour at ·35lb. fuel per horse-power hour would be 99·75lbs., which required for its complete combustion 1,505lbs. air. Now if the cylinder were filled with pure air at atmospheric pressure and temperature, by perfect scavenging, its capacity would be 2,880lbs. of air or 90 per cent. more than that required for complete combustion. Hence it might be possible to burn 90 per cent. more fuel per stroke and thus generate 90 per cent. more heat, a very considerable and undesirable temperature overload. The surplus air, when burning fuel to give 100lbs. mean pressure, acted merely as a diluent and might be replaced, as in the case of imperfect scavenging by exhaust gases, provided the scavenging and fuel injection arrangements were such as to give the oxygen free access to the fuel.

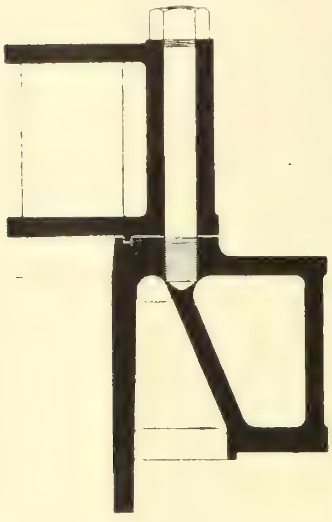


FIG. 4.—REIHERSTIEG-CARELS.

A series of experiments on these two systems of working, viz., diluent in one case pure air supplied at atmospheric temperature, and in the other case exhaust gases supplied at exhaust temperature, would be most instructive. Such an experiment would probably show a thermal efficiency in favour of the exhaust gas diluent.

Now if the scavenging arrangements supply only sufficient air to give 75lbs. mean pressure, then the fuel economy would be about the same as for 100lbs. mean pressure, as it was a well-known fact that the fuel economy of the Diesel engine did not vary much between five eighths load and full load. The weight and cost economy, however, would suffer, but it would still be 50 per cent. better off in this respect than the 4 stroke. In mercantile marine work the weight economy was not important, and there was a good margin in weight over the steam plant. Nothing, however, could yet be said about cost economy, and whether there was any likelihood in the future of a margin over the steam plant costs.

As regards the reason why the normal mean pressure in 2-stroke engines was less than that of the 4-stroke, the answer appeared to be that the present design of 2-stroke engine cylinder had just overstepped its temperature limitations. If, however, improvements could be made in the cylinder design to enable it to deal with a greater amount of heat, there was no reason why the mean pressure should not be equal to that of the 4-stroke, and if an overload was required the Sulzer auxiliary ports could be adopted.

Mr. Carels referred to troubles with the starting valve. In the first place it was a valve opening inwards and therefore an abomination. It was also liable to stick, and further, it was quite possible that the use of starting air in the power cylinder itself might be responsible for cracks initiated during manœuvring. Air at 500lbs. pressure and atmospheric temperature, expanded down to atmospheric pressure, was lowered in temperature to about 280° below zero Fahrenheit. When manœuvring, the surfaces of the piston, cylinder cover, and cylinder walls were exposed alternately to air at a very low temperature and gas at combustion temperature. Where the design admitted it, it would be infinitely preferable to use the scavenging cylinder as the starting cylinder, as carried out in the Polar design, thus dispensing with the starting valve in the power cylinder cover.

Mr. Carels had not referred to another trouble experienced by some of the 2-stroke engines, viz., bearing troubles. In the ordinary 2-stroke engine, unlike the 4-stroke, the pressure on the top and bottom ends and the main bearings was always downwards, the result being that lubrication presented difficulties. The first bearings to show trouble from this unidirectional thrust were the top ends, and these were now fitted with some system of forced lubrication. Now the bottom ends of the main bearings might run satisfactorily with drip lubrication, provided everything was nicely adjusted and the brasses were in first-class order. If, however, there was a slight want of alignment, due perhaps to the working of the ship in a sea way, or if any of the bearings commenced to heat up, the trouble would be cumulative and might lead to a compulsory stoppage. One remedy for this ever-present danger would be the use of forced lubrication all over, as was carried out in some engines, but this entailed a totally enclosed engine which was not yet popular with sea-going engineers. An alternative method and one which had many other advantages, was to cushion the reciprocating weights on the down stroke by an air cushion. This system was used by the National Gas Engine Company, and the Westinghouse Gas Engine Company, in their 4-stroke vertical tandem cylinder gas engines. An air cushion was also used by Willans & Robinson in their steam engines. It, however, cushioned the up-strokes and was intended to keep the connecting rods in "constant thrust" by absorbing the inertia of the reciprocating parts on the up-stroke. The following was an abstract from a letter Mr. Cummins had received from the National Gas Engine

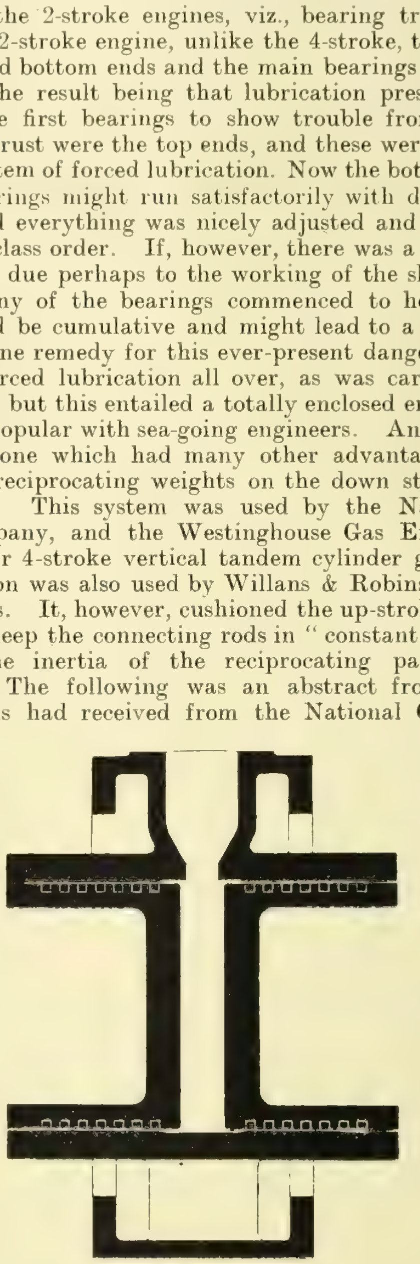


FIG. 5.—JUNKERS.

Company: "Cushioning is adopted in all our vertical tandem gas engines. We consider the arrangement most satisfactory, both as to obtaining sweeter running of the engine, and also improving the turning effort, as an engine working on this arrangement is practically a double-acting engine. As you will readily understand, the cushioning takes place between the top piston and the cover over the bottom cylinder. This cushion cylinder is fitted with a shifting valve and a relief valve, so that the air under the piston shall be compressed from

atmospheric pressure up to such a pressure as to absorb the inertia forces of the reciprocating parts."

Fig. 7 showed how the cushioning could be applied to a 2-stroke single-acting Diesel engine. It would be seen that the power piston was stepped to form the scavenging piston. The scavenging piston worked in a cylinder of which the upper part formed the scavenging pump. The lower part formed the

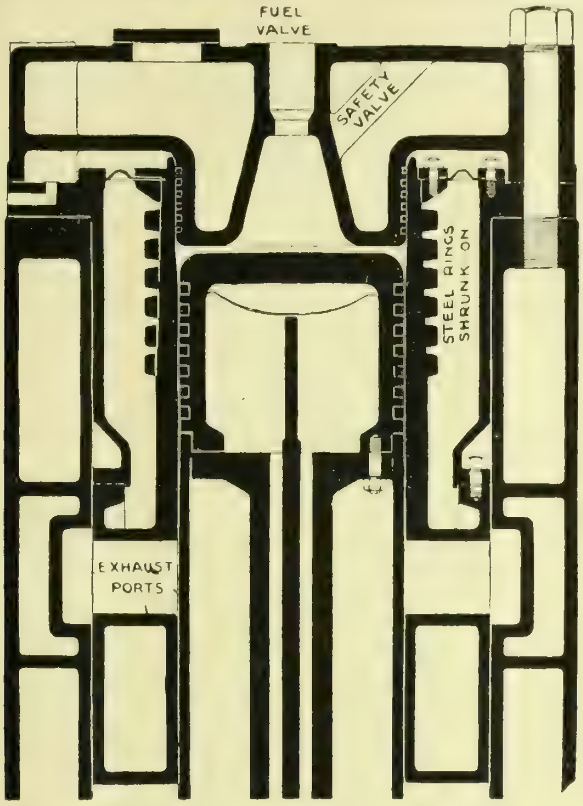


FIG. 6. CUMMINS DESIGN. (PATENT APPLIED FOR.)

cushioning cylinder when the engines were running normally, and the starting cylinder when manœuvring. On the down-stroke, air was compressed in the cushioning cylinder to about 45lbs., which would just balance the inertia of the reciprocating parts. At the bottom of the stroke, therefore, there was no load on the main bearings, nor on the top and bottom ends, and the lubricant could distribute itself freely over the surfaces. In an uncushioned engine with, say, a 20in. cylinder, there was a useless load on the bearings at the bottom of the stroke of about 15 tons. In a cushioned engine this load was bottled up in the cushioning air ready to do useful work on the up-stroke. The work thus stored up in the cushioning air during the down-stroke was able to do about 70 per cent. of the negative work of compression in the power cylinder on the up-stroke. In the ordinary way the whole of this negative work was done by the flywheel, or the other cylinders, acting through the crank shaft and the connecting rod. If therefore cushioning was used the bearing surfaces on the up-stroke had 70 per cent. less work to do than the uncushioned engine bearings.

The arrangement made the engine, in a sense, double acting, and much improved the turning effort and the mechanical efficiency. In the ordinary Diesel engine, owing to the high working pressure, the weight of the reciprocating parts was naturally much greater than that of the steam engine. This extra weight, especially if associated with higher revolutions, largely increased the inertia effect. This was of great advantage at the top of the stroke, as it decreased the initial load on the bearing surfaces during the latter part of the compression stroke and the first part of the power stroke. For instance, suppose the inertia effect at the top of the stroke was equivalent to 125lbs. per square inch in the power cylinder, then the initial load on the bearings was reduced 25 per cent. At the bottom of the stroke the increased inertia effect was an unmixed evil, as it placed a quite useless load on the bearings and prevented proper lubrication. If, however, the down-strokes were cushioned a large inertia effect was advantageous, as it made the engine more nearly double acting, decreased the loads on the bearings, improved the turning effort, and enabled a larger proportion of the negative work of compression to be done by the cushioning air, and thus tended to keep the pressure on the guides in one direction.

Referring again to Fig. 7, the starting valves for manœuvring were arranged to admit and exhaust air to and from the under side of the large piston, which was about 2½ times the area of the power piston, consequently starting air of 150-200lbs. pressure would suffice. As the power cylinder was not used for starting, the objectionable valve in the cover was dispensed with, and the fuel could be admitted to the power cylinder at the same time as engines were being manœuvred by air. Thus, during manœuvring, there was air pressure under the large piston and gas pressure above the power, thus getting a double-acting engine and much increasing the handiness during manœuvring. It would be noticed that the large piston was bolted to the under side of a large flange on the top of the piston rod and that the power piston was bolted to the top of this flange, the same bolts serving both purposes. By lowering the cover of the cushioning cylinder, and taking off the nuts of the connecting bolts, the large piston could be lowered out of its cylinder and the rings examined or replaced. At the same time the power piston could be drawn upwards in the usual manner. There was no need to disconnect the piston rod from the crosshead for this operation. This design removed the chief objection to the stepped piston of the M.A.N. engine. It would be noted that the scavenging pump delivered air at normal temperature when manœuvring.

In the Polar design, air which had been used for starting, and was therefore much below atmospheric temperature, was used for scavenging during manœuvring, the result being that the first compressions in the power cylinder would not effectively ignite the fuel owing to want of temperature. This, of course, entailed more starting strokes and waste of manœuvring air.

With regard to the question of cast-iron columns *versus* wrought-steel columns, it certainly seemed the right thing to take these enormous loads by wrought steel rather than cast iron, which entailed not only largely increased weight, but also a high quality of material. Transverse stiffness was very necessary in the case of the marine Diesel, in order that the alignment of the cam shaft and gear might not be affected by the motion of the ship. The Carels design achieved this by

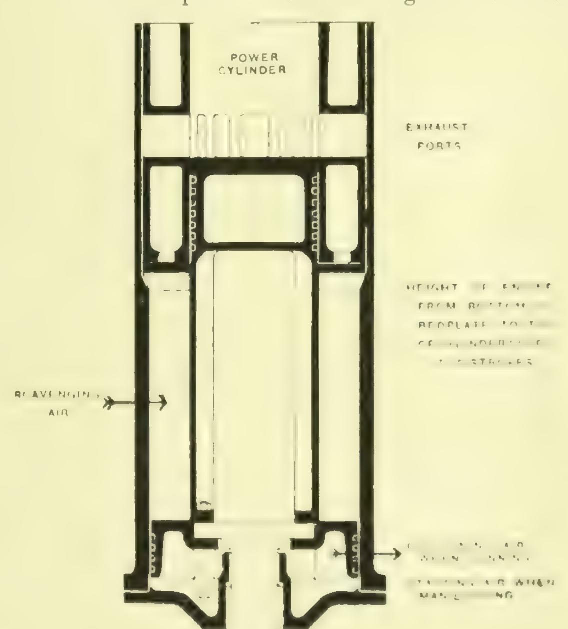


FIG. 7.

heavy cast iron columns well spread at the base, and the Werkspoor aimed at the same result by the use of steel diagonal stays, which, however, suffered from want of base. As the future tendency would probably be towards the use of long strokes, a useful combination would be wrought-steel columns as in the Werkspoor to take the main engine stress, and light well spread cast-iron columns to give transverse stiffness.

In conclusion, it might reasonably be said that the various mishaps to Diesel engines would not be an unmixed evil, as they had the effect of postponing for a time the general adoption of the Diesel engine for marine work in this country and enabling engine builders to study the problem closely and prepare their designs.

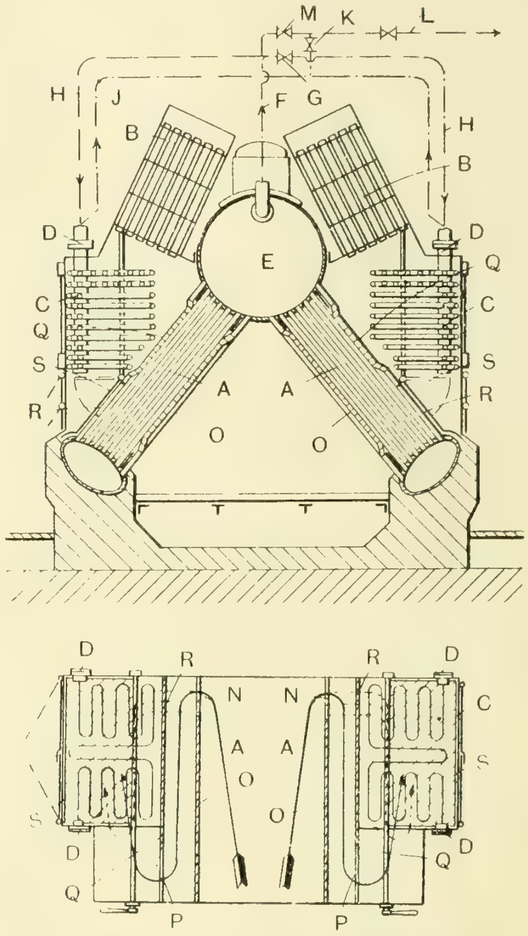
Mr. Carels, in replying, said that Mr. Cummins' contribution appeared to be a remarkably clear and comprehensive study of the present designs, and the system proposed to obviate the essential faults of existing designs was worthy of close consideration. A design evolved now naturally benefited by all the experience previously gathered. There were one or two points about it such as the high-pressure joint of the cylinder cover that did not satisfy Mr. Carels. Some difficulty would certainly be experienced in removing this cover after long runs, because the rings were bound to be choked up. Again, such an engine would be higher than the ordinary type, it was also rather complicated and would not be very cheap.

Perhaps Mr. Cummins' criticism of actual designs was a little too severe. Certainly some of those designs would have to be altered for high powered engines, but for the powers of which they were built there was every reason to think that they would meet their requirements quite satisfactorily. It was useless to borrow trouble. A complication in design that might be absolutely essential to reliability in, say, a 1,000 h.p. cylinder, must not necessarily be applied in one of 250; and the truth of the statement that the actual types of 2-strokes "had just overstepped their temperature limitations," as Mr. Cummins put it, was doubted. Nevertheless, Mr. Carels would emphasize how much he liked Mr. Cummins' design, and its careful and logical elimination of all features that might give rise to difficulties, and he wished him the best success in his attempt to arrive at perfection.

SUPERHEATERS FOR WATER-TUBE BOILERS.

Heretofore difficulty has been experienced in superheating systems for marine boilers of the type in which the superheater is arranged in the path of the furnace gases, owing to the fact that the boiler has to satisfy varying demands without diminution in economy or efficiency. Moreover the high temperatures of the furnace gases, during long and forced running, present considerable difficulties in working with superheaters. The accompanying illustrations show diagrammatically an arrangement of water-tube boiler designed and patented by The Vulcan Works, Hamburg, which it is claimed permits of a simple and wide range of regulation. The superheaters C are arranged within the boiler, between the water tubes A and the preliminary air heaters B, the superheaters consisting of a number of separate tubes bent into coils, the ends of which are connected to front and rear steam chambers D. Owing to the position of the chambers D, which are readily accessible from the exterior of the boiler, the superheater tubes can be easily fitted, inspected, and cleaned at any time without necessitating long dismantling operations. When the superheaters are in use, the saturated steam coming from the boiler E passes through the pipe F, the valve G, and the pipe H, to the front steam chamber D, and traverses the superheater tubes C, where it is superheated, and thence passes from the rear steam chambers D, through the pipe J, the valve K, and the pipe L to the engine. During that time the valve M on the pipe L is closed. The furnace gases rising from the firegrate pass through an opening N at the rear of the first row O of water tubes, which row is formed into a wall by bending and arranging the tubes in close proximity. The gases which follow the main or normal path traverse the water tubes from the rear to the front in a direction at right angles to the water tubes and then pass to the superheater tubes and to the stack or chimney through an opening P at the front of the outer row Q of tubes, which tubes are also arranged to form a wall.

The chief characteristic feature of the arrangement resides in the fact that a short or curtailed path is afforded for a portion of the gases through an opening R in the lower rear part of outer row Q, forming a tubular wall, the opening R being opposite the opening N. By means of adjustable flap valves or doors S located beneath the superheater tubes it is possible to regulate the quantity of gases passing through the opening R and also to cut off the gases entirely from this short path so that they follow the normal or main path. The gases which pass through the openings R when the doors S are in the horizontal positions shown in dotted lines are of relatively high temperature, and they pass under the doors S towards the front of the boiler where they meet the superheater tubes C and mix with the gases of relatively low temperature which escape through the opening P after passing in contact with the water tubes. The mixed gases traverse the superheater tubes and then pass through the air heaters to the chimney. The short paths to the superheater tubes are shown by dotted arrows and the main paths through the water tubes by full-line arrows. When the superheaters are not in use, the saturated steam from the boiler flows through the pipe F, the valve M, and the pipe L direct to



Superheaters for Water Tube Boilers.

the engines, the valve G being closed in this case. The furnace gases are caused to traverse the whole of the water tubes by moving the flap valve S to close the opening R, thus cutting off the short path to the space below the superheater. The path of the gases is then somewhat similar to that which takes place in the ordinary water-tube boilers. By partially opening the valves G and M simultaneously and by suitably adjusting the flap valve S, the effects of the superheater can be controlled within wide ranges, thus rendering it possible to obtain any degree of superheating desirable for marine purposes. By means of the flap valve S it is possible to determine or select the required final temperature of the steam leaving the superheater and, moreover, by regulating the valves G and M so as to mix the saturated and superheated steam, the temperature of the steam passing to the engine can be controlled.

The Utilisation of Solar Energy.—Mr. A. S. E. Ackermann, B.Sc., is to read a paper before the Society of Engineers on "The Utilisation of Solar Energy," embodying the results of his trials of engines for using sun-produced steam. The plant tested has cost some £30,000. The investigations cover nearly four years. The meeting is to be held at the Institution of Electrical Engineers, on Monday, April 6th, at 7-30 p.m.

EXPLOSIONS IN BLASTFURNACES.

At a recent meeting of the Cleveland Institution of Engineers a paper entitled "A Few Notes Relating to the Manufacture of Iron and Steel," was read by Mr. J. H. Harrison, M.Inst.C.E., in the course of which the author dealt with explosions in the upper part of blastfurnaces. These were, he remarked, often unfortunately attended with fatal results, and generally wrecked to greater or lesser degree the bell and hopper and upper part of the furnace. Frequently it was put forward that the initial cause was an explosion of gas in the upper part of the furnace, the effect of which was to drive the materials above the point of explosion out at the top of the furnace, together with everything standing in its course. Sometimes the side of the furnace was blown out by such explosion, probably due to this offering less resistance than the mass of materials above it. In the author's opinion these accidents were not due to explosions of gas at all, but to the sudden release of gases under comparatively high pressure into the top part of the furnace where the pressure was very low.

Many years ago the late Sir Lowthian Bell observed that ferric oxide had the property of splitting up CO into $C + CO_2$ at such temperatures as existed at the upper part of a blastfurnace. In all hematite ores and brown ores the iron existed largely as ferric oxide, and also in some others, and it had been observed that such ores had the quality of becoming to a greater or less degree impregnated with carbon, in some cases to such an extent as to considerably increase their volume. It was generally noticed that just before one of these disastrous explosions the furnace was hanging, and it was quite reasonable to assume that the cause of the hanging was the swelling of the ore due to the carbon impregnation referred to, and to the deposit of solid carbon upon the comparatively cold ore. This would cause resistance to the flow of the gases through the materials, and also would wedge the materials against the furnace sides, causing excessive friction against the side walls, and so resisting the descent of the materials, up to a point where the friction and the jamming against the walls became sufficient to prevent the further descent of the whole mass of materials above that point.

When we remembered that 1lb. per square inch of unbalanced gas pressure would support about one foot of height of raw materials, it was evident that with the restricted passages through the materials and the excessive friction on the side walls, which, under normal conditions, supported by far the greater part of the weight of the materials, a very little extra jamming due to some abnormal working of the furnace would bring about the arrest in the descent of what might be considered as a solid piston of materials, say 10 or 12 feet deep. Once such a piston came to rest it would not descend further until the resistance was removed, because the friction at rest was greater than the friction when in motion. In the meantime that portion below the affected piston continued to descend, and broke away from the materials above, leaving a gradually increasing space over the whole area of the stack. As this material continued to descend, it reduced in volume, due to tapping out of the melted slag and iron at the bottom; therefore the resistance through it to the ascending gases was reduced, with the result that the pressure of the gases increased in this space, which tended to further support the piston above. Meanwhile, the furnace having been hanging, no cold materials would be charged into it, and the gases from below the piston having been coming through to it at increasingly higher temperature, this piston would get hotter and hotter, bringing about more rapid chemical action. Reduction of the ore would become more rapid, and the carbon deposited upon it at the lower temperatures would be burned out by the oxygen liberated from the ore at this higher temperature. As a result the mass would begin to shrink and break away, and finally would slip down bodily and fall into the space below. The hot gases would be compressed to a pressure sufficient to burst through the mass of hot materials above, and would then get vent upwards through these materials, carrying a portion of them with them into the comparatively low pressure above, lifting the bell and hopper out of place and everything in the direct line of the force of the explosion. Any men working round the top of the furnace at the time were generally badly burned by the hot gases and injured by the flying materials

The bell and hopper were usually very heavy masses, and it might be supposed that it would not be possible to get a pressure at the top of the furnace by simply blowing blast in at the bottom sufficient to lift the bell and hopper without some combustive explosion of gas. But say the weight of the bell and hopper was 16 tons, and the diameter of the throat of the furnace was 15ft., it was only necessary to have a gas pressure under the bell and hopper of 1½lbs. per square inch to balance them. So that a pressure of, say, 2lbs. per square inch would easily throw the bell and hopper out of place, and it was quite possible in the way described to get even a higher pressure than this at the furnace top at the moment of the release of the pent-up gases.

It frequently came out in evidence, when enquiring into such unfortunate accidents, that explosion doors on the gas boxes, put there as safety valves in case of explosion, did not open at all. It was very unlikely that they would open in the event of such an explosion as that described, because the force and current of the explosion was directly upward, and the tendency would rather be to draw gas out of the down comers and to jam the explosion doors harder on their seats. But in cases of less severe explosions, where the pressure was not so great as to lift the bell and hopper, these doors were very valuable as a means of allowing the pressure of the gases to get vent quickly without doing any harm. Such slight explosions were not unusual when a furnace was stiff and hanging a little, and they took the form of a subdued roar, indicating that the piston of materials had broken down gradually and fallen into the space below piecemeal rather than in a solid mass. In such cases there was practically no compression of the hot gases in the space below, and these simply vented themselves gradually from the pressure which they had acquired, through the comparatively open falling materials and out by the explosion doors and lighters to the atmosphere as black smoke.

The author put forward another reason why it was clear these top explosions were not gas explosions, and which also tended to confirm the opinion expressed as to their real cause. It was generally noticed there was no sharp well-defined report attending these explosions such as occurred in the case of a gas explosion, but rather a comparatively long drawn-out roar, sometimes extending over several seconds and much more subdued than a gas explosion. Indeed, the author had known of one such explosion, which had disastrous and fatal results, in which the men working below at other furnaces in the same battery did not know that anything unusual had occurred. He had also heard of cases where the side of the furnace had proved to be a point of less resistance in such explosions as described than the piston of materials jammed at the top of the furnace, resulting in the side of the furnace being blown out by sheer pressure of the gases within the space below the piston, and throwing the hot materials over the pig beds and on to the men working below, with fatal results.

The only remedy, the author observed, was to make the lines of the furnace such that from the throat downward the walls should batter rapidly outward to the slack lines of a depth of about 15ft., making the rate of batter outward from that point to the bosh what was usually allowed. This 15ft. would about cover the depth where the sticking was most liable to occur, as it contained the coldest materials, and by so rapidly battering the walls back at this point it would be more difficult for the materials to stick to the walls. This design would necessitate a furnace with a larger bosh diameter than was usual in modern furnaces, and also a furnace of larger cubic capacity, but this would lead to more regular work in the furnace, as the velocity of the gases over the ore would be slower and they would be longer in contact, both of which conditions tend to the more complete reduction of the ore before it reached the melting zone.

The Glasgow Royal Technical College Scientific Society.—At the annual general meeting of this society, held on Saturday last, Mr. John Y. Moyes presiding, Mr. Joseph Menmuir, of Messrs. Kelvin, Bottomley, & Baird, was elected president for the coming session. Messrs. David Keachie, Peter Stobie, and William Yuill were elected vice-presidents. Afterwards Mr. William Kerr read a paper on "The Elastic Problems of the Steam Turbine Rotor."

THE RUNNING OF GAS ENGINES AND GAS PRODUCERS.*

BY W. A. TOOKEY, M.I.M.E., M.I.A.E.

(*Concluded from page 285.*)

BEFORE passing to speak of other topics a word or two should be said upon the subject of water circulation through the cylinder jacket, as this has quite as much effect on the ignition timing as the compression pressure. An unduly large number of engines suffer from overheating of the cylinders through imperfect circulation of cooling water. In some of these inadequate provision has been made for the proper and automatic supply of "make-up" water for the one or more tanks provided by the makers with the engine. The consequence is that the level of the water in the storage tanks is often below the top of the flow pipe, which enters the top of the hot tank, whereas there should be always one or two inches of "cover." It does not seem to be considered necessary by some users of gas engines to take any trouble to ensure proper circulation of the cooling water, but, instead, if the cylinder becomes overheated, it is deemed sufficient to turn on the town water to the tanks, even, in some instances, without ensuring that the cold water shall first flow through the engine cylinder. Such cases may be taken as extreme and indicative of ignorance rather than indifference. But there is less excuse for those engineers who, in planning out the connections of water circulation devices, take no precautions to ensure the continued circulation of water after the engine has been stopped, and more fractures of large gas engine cylinders and covers have been started by the neglect of this precaution than is usually recognised. The circulation of water through the jackets of internal-combustion engines should be continued after their stoppage and until all chance of overheating through transmission of heat from the internal walls of the cylinder has been nullified. In some installations the subject has received consideration, for non-return valves have been provided for the retention of the water in the jackets when centrifugal circulating pumps have been fitted to prevent all the water draining away to the suction level through the pump casing. This, however, is not enough, for the quantity of heat stored in the cylinders of gas engines of fair size, after stoppage, is very considerable, and likely to cause more incrustation upon the walls during stoppages than probably occurs during working hours. Back pressure valves have a bad habit of leaking on occasion, and this brings in another argument in favour of definite provision being made for some mechanical or automatic device for maintaining the continuance of water circulation for some hours after the engines have been brought to a standstill. Recently the author heard of a fractured cylinder which failed just around that portion of the circumference to which the water level was permitted to fall after the circulating pump had ceased work. It is very desirable either to filter the water drawn from rivers or streams before passing it through the cylinders of gas engines in rural districts, or to force it through the jackets at such velocity that it has no time to stagnate in corners or "pockets," and thus no opportunity be given for the deposition of solid matters in suspension. In any case, it is advisable not to allow the temperature of the water to rise above 140° Fah., for, above this temperature, some of the salts held in solution are thrown down and excessive differences in temperature may then occur locally, involving undue stresses which may result in a claim being made upon the insurance company, with a consequent increase in the number of bad marks scored against large gas engines in the records of that particular company.

During the last ten years considerable improvements in gas engine design and construction have been made. The coming of the suction gas producer in the years 1902 to 1905 has resulted in a rapid development of the larger sizes of gas engines, and, as time goes on, the records of the gas engine industry show that the average size of engine sold is always on the increase. Time forbids the mention of all the many improvements in detail that offer themselves for comment, but reference may be made to several of the more important. First of all magneto ignition, with provision for ready adjustment over a wide range, is now an integral part of a modern gas engine. The proportions of both air and gas can be readily adjusted to suit any quality of gas that is available. Lubrication of all details is carried out in a scientific manner, which reduces the cost of operation very considerably, besides lessening the wear and tear of all mechanical details. Cylinders are supplied with oil under pressure. Piston pins are fitted with separate lubricators, and are no longer dependent upon the haphazard method of being fed by drips from a recess formed upon the circumference of the pistons from which the oil passed through the piston walls, and, if not shaken off by the reciprocation of the piston, eventually found its way to another recess in the piston pin bearing, and from thence to the pin itself. Main bearings, and in some instances cam shafts bearings, are fitted with oiling rings. The crank pins are fitted with continuous oiling devices. The engine frames are provided with a lip cast around the base to prevent the oil flowing over the cement foundation and disintegrating the concrete. All these points make for economy and efficiency, and reduce the risk of breakdowns.

The author is frequently asked for information as to the gas consumption of engines at full, half, and three-quarter loads, and particularly in connection with the generation of electric current. As a rough guide, it can be said that whatever the calorific value of the gas used, the gas engine of to-

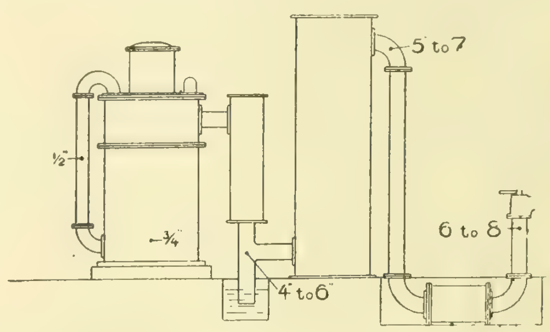


FIG. 3.—DIAGRAM SHOWING NORMAL NEGATIVE PRESSURES (INCHES OF WATER) IN SUCTION GAS PLANTS.

day can safely be relied upon to develop one brake horse-power hour for every 10,000 B.Th. U. in the fuel under full load conditions. As a matter of fact, the performances of engines when in good order and properly adjusted, prove that one brake horse-power hour can be obtained for about 8.250 B.Th. U.—equivalent to a thermal efficiency of 31 per cent., but being dependent upon the clearance volume ratio, as shown in Fig. 2. In actual work the full load outputs can be taken as being obtainable with the mean of these two figures, say, 9,000 B.Th.U. per brake horse-power hour. The actual gas consumptions for any load other than full can be readily computed by assuming that the mechanical efficiency of the engine amounts to 85 per cent. at full load, and by deducting the horse-power this represents from the indicated horse-power developed at any point of the load range. For example, in the case of an engine capable of developing 100 b.h.p. at full load. At 85 per cent. mechanical efficiency the indicated horse-power would be 118 in round figures, and the frictional horse-power would be the difference between these, or 18 h.p. At three-quarter load, therefore, 75 b.h.p. would be equivalent to $75 + 18 = 93$ i.h.p., and as 9,000 B.Th.U. per brake horse-power would be equivalent to $\frac{9{,}000 \times 100}{118} = 7{,}650$ B.Th.U. per indicated horse-power, so the consumption of gas at 75 b.h.p. would be $7{,}650 \times 93 \div 75 = 9{,}500$ B.Th.U. At other outputs estimated consumptions can be calculated in a similar manner, as for practical purposes it can be accepted as a matter of fact that frictional horse-power would be much the same at all loads, and given proper adjustment of mixture, regulation, and ignition timing, the consumption per indicated horse-power would remain practically constant, except perhaps at the lightest loads.

* Abstract of paper read before the Junior Institution of Engineers, March 16th, 1914.

For gas engine and producer gas installations, test results have proved that one brake horse-power can be obtained for one hour with a consumption of 0·75lb. of anthracite when every detail is working at its best, and the engine is fully loaded, and therefore at highest mechanical efficiency. In practice, and for estimating purposes, it is usually considered that the round figure of 1lb. of anthracite per brake horse-power hour gives a sufficiently close approximation to the everyday conditions, with, say, two-thirds full load, and with fuel of average quality and ash content. Records of performances of many engines and producers driving dynamos demonstrate that the overall fuel consumption under ordinary factory conditions, and including all standby and other losses, runs out at about 1½lbs. of anthracite of average quality per brake horse-power hour, or 2lbs. per kilowatt hour, and, with bituminous coal, 3lbs. per kilowatt hour.

Town gas engines, with a fair load in proportion to rated full load output, consume about 14,500 B.Th.U. per kilowatt hour. If gas of 500 B.Th.U. per cubic foot is available at, say, 20d. per 1,000 cub. ft., one unit of electricity—one kilowatt-hour—can be generated for 0·6d., of course for fuel cost only. Comparing a gas engine consuming 20 cub. ft. of 500 B.Th.U. gas per brake horse-power hour with the cost of running an electric motor, on fuel cost alone, and assuming an efficiency of the motor of 90 per cent. gas at 20d. per 1,000 feet would require the cost of current to be 0·48d. per unit for equivalent cost. In other words, it could be stated that a gas engine with town gas service of 500 B.Th.U. per cubic foot, at 20d. per 1,000 cubic feet, could be permitted to run at such a light load with considerably diminished mechanical efficiency, or, under normal load, be permitted to deteriorate into such a state of disrepair that the rate of gas consumption could rise to 40 cub. ft. per brake horse-power hour, before it would be equivalent, in fuel cost only, to the cost of electric current at 1d. per unit. Naturally, the relative advantages of gas engines and electric motors cannot be summed up in a few words, but these comparative figures will be interesting to members concerned, either in the gas or electric industries.

During the last eight years many new types of gas generators have been brought out, with the result that suction gas producers can now be obtained capable of utilising all kinds of combustible material.

The attendant of a gas plant usually finds that there are but a few points which need his constant care. Probably his attention has to be given to the management of the producer more frequently and carefully when the fuel provided for his use is of poor quality, either containing a high proportion of dust or disintegrating upon heating and forming small particles which clog the apertures through which the air drawn in must pass. Similarly with coals having a relatively high ash content, the attendant is required to take proper precautions by dislodging the accumulation of ash and dust at regular intervals, in order to maintain sufficient freedom of passage for the entering air to pass through the fuel bed and to be duly converted into good gas. It is important to restrict the differences in pressure prevailing below and above the fuel bed, so that the lighter particles are not lifted from the upper portions of the fire and are not carried along with the outflowing gas to be finally deposited in the connections between the generator and the scrubber. The production of producer gas being of the nature of a chemical process depends for its efficiency and its continuity upon the maintenance of uniform conditions, which, from the circumstances, cannot be guaranteed. It is therefore to be expected that from time to time the calorific value of the gas produced must vary, particularly when sudden changes of load occur, and before and after charging, poking, or clearing the fires, which, by-the-way, should be performed at regular intervals to maintain the efficiency of the chemical process as uniformly as possible. There are two methods by which the attendant can be informed as to the maintenance or otherwise of the essential conditions necessary for the production of good quality gas from suction gas plants. One is by observing the pressure differences that exist at various portions of the apparatus, and, in the case of irregularities, to take such steps as will maintain such pressure differences as experience dictates. The other method is to pass some of the gas, under pressure, through a recording calorimeter and thus to obtain visible indications of the variations of gas quality that take place under different working conditions. To do this, however, involves the use of a fan which has to be power-driven—a matter of some consideration in many factories but, if circumstances will allow it, the installation of a recording calorimeter is well worth while.

In the absence of a recording calorimeter, however, the observations to be made from a series of water pressure gauges are of practical value, for by such means undue restriction in any part of the plant can be readily detected. The permissible differences in water-gauge pressures throughout a suction plant are indicated in Fig. 3.

Occasionally it is found that a gas producer which has been giving efficient service for a considerable period will "heat up" at one or more points of the generator, the casing becoming red hot, either above or around the fire door, or near a poking door at the base of the fire, or at the top plate, or in the gas-outlet pipe from the generator. When this occurs it is a certain indication that at such points there is an air leakage into the apparatus of such amount as to cause intense local combustion. Steps must be taken to obtain proper seating of the fire door, or poking-plug cover. All chances of air leaking into the generator through the top plate joints or top poking holes must be provided for, as the entering air involves combustion of the gas rising from the fuel bed, not only vitiating the gas produced, but creating temperatures that may result in fractures of the top cover or the outlet pipe. Leakages of air from the ash pit through the bricks from the outside of the furnace walls are not easily detected, but they are indicated by increased consumption of fuel and necessity to close the engine air regulator to a greater extent to induce a larger quantity of poorer gas to take part in combustion within the engine cylinder.

Corrosion of steel-plate casings around the base of generators and scrubbers is now obviated by the substitution of cast iron for these portions wherever practicable. Facilities are also provided for the ready removal of deposit and silt from the base of the down pipe between the generator and scrubber, and from the seal pot into which this down pipe dips. In many of the modern type coke scrubbers particular attention is paid to the sprinkling device distributing water over the coke bed in order to avoid the whole or partial blockage of water apertures by reason of the solid impurities present in the water. The scrubbers are also divided into upper and lower sections, so that the coke resting upon the bottom grid can be changed the more frequently without necessitating the disturbance of the upper portion of the coke. The gas inlet to the scrubber is also made in such a way that any deposit forming at this point can be readily removed.

There is one other point of practical importance that calls for mention, and that is in connection with the supply of water to the vapour chamber, intended to humidify the air before the latter enters the fuel bed. In this respect the attendant has very little concern except to take such steps as will ensure that the amount of water entering, when once adjusted, shall not vary whatever the load upon the engine, and to take care that final adjustments to the water regulator are made only after the producer has attained its normal working temperature, which it will do soon after the engine has been set to work under load. All that is necessary is to see that as much water as will evaporate is permitted to enter the vaporiser, and this is easily proved by ensuring that some of the water escapes as such from the overflow pipe of the vaporiser in a constant succession of drops. There is no need to try to adjust the amount of water entering the vaporiser according to the load under which the engine may be working from time to time. The quantity of air entering the generator is decided by the number of impulses taken by the engine, or rather by the amount of gas required by the engine to deal with its load, and it is merely necessary for the air to be saturated with water vapour at its normal working temperature of admission to the furnace. Consideration will show that, if the load upon the engine results in generator temperatures higher than normal, then the temperature of the entering air will be raised, and the amount of water vapour absorbed will also

be increased, and to an extent which will tend to counteract the increased furnace temperatures. On the other hand, any decrease in furnace temperatures consequent upon light loads will tend to reduce the temperature of the entering air more or less, and the amount of water then absorbed will be decreased. So that the suction gas producer can be considered to be sufficiently self-regulating to work without attention to the water service, provided, as has been before stated, that the adjustment has been made by the attendant after normal working temperatures have once been established.

CLEANING OF BLASTFURNACE GAS.

A comprehensive paper on "Gas Cleaning at the Duquesne Plant of the Carnegie Steel Company" was presented by Mr. A. N. Diehl at a meeting of the American Institute of Mining Engineers on February 19th last. An average sample of the gas delivered to the gas engines was, he said, drawn over a period of seven hours each day. This was transmitted to the laboratory for analysis, which was reported back along with the calculated heat value in terms of net B.T.U. per cubic foot at 62° Fah. and 30in. of mercury. In conducting and reporting the various tests they had endeavoured to follow a standard method of procedure and form. The method adopted covered thoroughly the performance of the unit, including those items of observation which were of paramount importance, and they had found it most valuable. There was also a standard form for reporting dust and moisture determination on engine gas.

Until within the last six or seven months all moisture and dust determinations were made with the Brady apparatus. They found that the results on dirty gas could not be depended upon and were very inconsistent at times, and therefore adopted a method of dust estimation in dirty gas. On clean gas, however, the results obtained by the use of the Brady apparatus were sufficiently reliable for all practical purposes. Some few months ago a number of determinations of dust and moisture were made with the Brown apparatus, the results of which indicated accuracy and reliability. On engine gas very good results were obtained with the Brady apparatus.

In making dust and moisture determinations their aim had been to sample the gas at the same velocity as the gas flowing in the mains. With their present Brady apparatus this proved a little tedious on clean gas to stoves and boilers, requiring constant attention and adjustment on the part of the observer. However, on engine gas very little inconvenience was encountered from this source, and they had been able to maintain the proper velocity with comparative ease. The first dust and moisture determinations were made using volumetric tanks in determining gas volumes, which was found to be very inconvenient and decidedly limited. These had been replaced by wet test meters, and as a result they had sampled as much as 500 cub. ft. during a single test. Regular or daily determinations of dust and moisture had not been made since they had not been inconvenienced by excessive dust deposition, either in clean mains or engine cylinders. Tests indicated a very uniform dust content in clean gas, with the moisture practically corresponding to saturation at the off-coming gas temperatures, and at no time had they encountered mechanically entrained water in amounts to be detrimental.

The use of raw gas in stoves was conducive to low efficiencies. This was due primarily to the heavy coating of dust on the brickwork fusing in masses, thus preventing the absorption of heat, destroying the brickwork, and requiring constant attention to the removal of this material. During the periods of scraping out the combustion chamber, the stoves were burning gas very inefficiently, and at such times as the stove was off for complete cleaning the furnace was deprived of one-fourth of its blast heating capacity. The intermittent pressures also made it impossible to obtain a constant flue-gas analysis and allow either excess air or gas in the stack. The use of raw gas in the boilers showed a similar low efficiency, but not so marked. It was customary to blow off the tubes every 24 hours, and while the blowing was going on much excess air entered the combustion chamber. From the time the tubes were cleaned they started collecting dirt again and the steaming power suffered accordingly. Intermittent pressure also affected the boiler flue-gas analyses as in the stoves.

By the use of clean gas in the stoves they completely did away with cleaning stoves, had a constant pressure in the gas supply, and used an orifice plate over the air-inlet door, which gave an extremely constant and economical flue-gas. The saving on clean gas over dirty gas on stoves amounted to 0·1591 cent per ton of iron. The use of clean gas in the boilers gave the same benefits in operation. The thoroughly cleaned gas was used only for engine purposes. Within a few hours after starting, all exposed parts inside of the cylinders except the wearing surface became coated with a light brown deposit. It had been their experience that if oil could be kept away from these surfaces this deposit was only very slightly increased by further operation of the engines. In the combustion chambers, where there was never any oil present, the deposit was so even that they had operated cylinders for nearly four years without cleaning these surfaces, and considered that the presence of such an even coating was an advantage, having an insulating effect, and protecting the metal from the direct action of the hot gases. However, where an excess of oil was present, as on the inside of the cylinder head directly below the piston rod (the oil being carried in by the rod), the dirt accumulated more rapidly and often very unevenly. If an engine was shut down and the head allowed to cool, then started and brought up to working temperature again, the contraction and expansion of the head broke the accumulated oil and dirt loose in the form of scale or blisters, the edges of which were easily heated and caused premature explosions. Usually this scale would partly break off, due to these premature explosions, and trouble at this point usually ceased until the next time the engine was stopped and started. When this trouble occurred too frequently the engine was shut down, the cylinder examined through the air-starting check valve opening, and the deposit scraped off if possible. If too hard or too extensive an accumulation was found, the head was pulled out and the surfaces thoroughly cleaned. Following this procedure they had some cylinder heads on their blowing engines that had not been out for over 18 months. Previous to August, 1913, when new piston rods were installed in the two power engines, practically every cylinder on the two engines had been closed up for more than a year, although examined through the starting-valve opening at shorter intervals.

They had an advantage over engines with exhaust valves directly in the bottom of the cylinder in that the oil and dirt that accumulated here did not interfere in any way with the operation of the valve, but could be blown out through the drain valve, with which each end of each cylinder was equipped. These valves were held open for two full cycles every three hours. Their experience indicated that with their type of engine they could operate from 12 to 18 months without removing heads for cleaning, the smaller particles of dirt being removed at lesser intervals, and also that the cleaning was necessary principally from the fact that oil was present. The portions free from oil were covered so evenly that the presence of the deposit was an advantage.

Using dirty gas for boiler firing the efficiency was 50·48 per cent., and with clean gas it increased to 59·05 per cent. The tests were run on boilers of the same make, type, and rating. The boilers working on clean gas developed but very little more than the builder's rating, although working at a higher efficiency than those on unwashed gas. This was due to an insufficient gas supply, which was directly traceable to undersized mains and connections, the mains having been so designed as to take care of only 1,500 boiler horse-power of boilers on clean gas. In this case, however, the operation of approximately 3,750 boiler horse-power was attempted, resulting in a gas shortage for each of the respective units. The above tests were also run under normal conditions, and were therefore representative of working performance. It had been their experience recently that steam could be raised very quickly on washed gas, and they had put such boilers on the line at 140lbs. to 150lbs. gauge from feed water at 70°, in 30 to 45 minutes. Due to very uniform gas pressures the boilers on washed gas steamed very regularly.

THE INFLUENCE OF NICKEL ON SOME COPPER-ALUMINIUM ALLOYS.*

BY PROF. A. A. READ, F.I.C., AND R. H. GREAVES, M.SC.

ALTHOUGH alloys containing copper, nickel, and aluminium have been used commercially from time to time, no systematic study of their properties appears to have been published. The authors therefore undertook to investigate the influence of nickel, chiefly on two typical commercial copper-aluminium alloys, namely, those containing 5 and 10 per cent. of aluminium respectively.

For the purpose of carrying out this research the following materials were procured: Electrolytic or cathode copper of

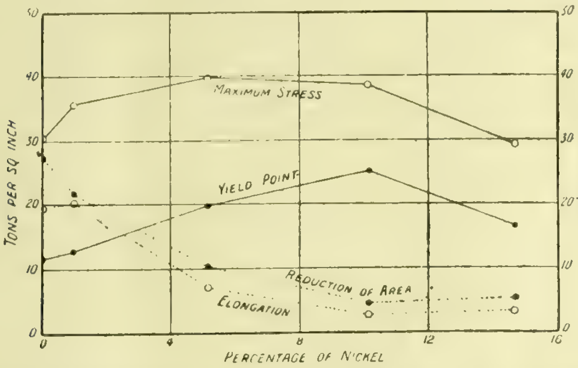


FIG. 1.—TENSILE TESTS. ALUMINIUM 10 PER CENT. CHILL CASTINGS.

very high purity from Messrs. Vivian & Sons, Swansea. Shot nickel containing at least 99·8 per cent. of nickel from the Mond Nickel Company; this, on analysis, gave: Silicon, 0·01 per cent.; iron, 0·04 per cent. Aluminium of guaranteed purity, 99·5 per cent., from British Aluminium Company; this was found on analysis to contain: Silicon, 0·17 per cent.; iron, 0·18 per cent.; sodium, 0·05 per cent.

Estimation of Copper.—The copper was determined by the iodine-thiosulphate method.

Estimation of Aluminium.—This has been taken by difference, which probably involves less error than a direct determination.

Melting and Casting of the Ingots.—The copper and cupro-nickel were melted together under charcoal in a Salamander crucible, heated in a coke wind furnace. The metal was

TABLE I.—*Composition of the Ingots.*

No.	Copper per cent.	Nickel per cent.	Aluminium per cent.
1	89·94	–	10·06
2	89·14	1·04	9·82
3	87·66	2·46	9·88
4	85·11	4·95	9·94
5	82·82	7·48	9·70
6	94·98	—	5·02
7	93·96	0·94	5·10
8	92·68	2·38	4·94
9	89·84	4·84	5·32
10	87·48	7·31	5·21

teemed at as low a temperature as possible into a circular cast-iron chill mould, following up with fluid metal from the pot to avoid the pipe which would be caused by shrinkage. The ingots thus cast were 2¼in. diam., 18in. in length, and weighed about 20lbs. The time from charging the cold metal to teeming was about one hour. The maximum loss of aluminium was 0·4 per cent., the average loss being about 0·2 per cent. There was no loss of nickel. Ten ingots were cast, and on analysis gave the results shown in Table I.

Rolling of the Ingots.—The eight ingots containing nickel were all heated up to the same temperature together and rolled down with one reheating to 1in. diam. In each case the reheating was done when the diameter had been reduced to 1¼in. The temperature required for rolling was higher than for ordinary aluminium bronze, and the metal was noticeably harder. The alloy which appeared to be hardest on rolling was No. 10 with about 7½ per cent. of nickel and 5 per cent. of aluminium; next were Nos. 5 and 4 with 10 per cent. of aluminium and 7½ and 5 per cent. of nickel respectively. One half piece of each of the hot rolled rods was then cold rolled with four passes; another small piece was rolled hot down to ½in. diam. and then cold rolled with three passes. With the exception of the difference in hardness already mentioned, all the alloys behaved similarly in rolling, yielding perfectly sound rods. Nos. 1 and 6, containing no nickel, were rolled hot down to $\frac{15}{16}$in. full diameter, and the cold working was carried out on one half piece of each rod by drawing through a die (cold drawing).

Wire-drawing Tests.—A portion of each rod was turned down to $\frac{3}{16}$in. diam. for wire drawing, which was carried out first on a small draw-bench, and afterwards by hand. All

TABLE II.—*Wire-drawing Results.*

No.	Composition.			Finished at	
	Copper per cent.	Nickel per cent.	Aluminium per cent.	Hole (1 to 50).	Corresponding diameter in inches.
1	89·94	—	10·06	44	0·047
2	89·14	1·04	9·82	48	0·040
3	87·66	2·46	9·88	40	0·058
4	85·11	4·95	9·94	15	0·123
5	82·82	7·48	9·70	8	0·153
6	94·98	·	5·02	50	0·033
7	93·96	0·94	5·10	50	0·033
8	92·68	2·38	4·94	50	0·033
9	89·84	4·84	5·32	50	0·033
10	87·48	7·31	5·21	50	0·033

the wires were quite sound and smooth, and, judged by their behaviour in the wire-drawing tests, the alloys of the two series stand in the following order:—

Aluminium, 10 per Cent.—Nos. 2, 1, 3. All these, however, broke even after repeated annealing before hole 50 was reached. Nos. 4 and 5 practically could not be drawn.

Aluminium, 5 per Cent.—Nos. 7, 8, 9, 10, 6. It will be noticed that all the members of this series could be drawn through the last hole (50), diameter 0·033in. The behaviour of the material containing nickel during these tests was found to be very much better than that of the pure 5 per cent. aluminium bronze, thus showing that the presence of nickel improves the ductility of this alloy.

Tensile Tests.—In the tests about to be described, "H" refers to the cold rolled metal, "A" to the annealed and slowly cooled, "N" to the air-cooled, and "Q" to the

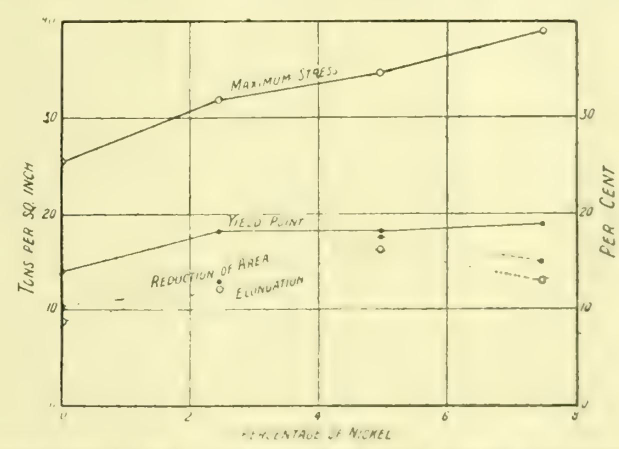


FIG. 2. TENSILE TESTS. ALUMINIUM 10 PER CENT. ROLLED AND ANNEALED.

quenched material, while "C" indicates the chill castings. These latter were 1in. diam. and 10in. long. The annealing was carried out by heating the rods with a pyrometer attached, in a closed gas muffle, to 900° C., and keeping them at this temperature for 15 minutes. The gas was then turned off, the damper closed, and the rods, after being allowed to cool slowly, were withdrawn when quite cold. The rate of cooling may be judged from the fact that the temperature fell to one half in 90 minutes. Some preliminary experiments, in which the hardness of a number of annealed samples was measured by the scleroscope, showed that the annealing

* Abstract of paper read before the Institute of Metals, March 18th, 1914.

of the 10 per cent. aluminium alloys containing nickel was incomplete at 800° C. for 15 minutes; but after annealing at 900° C. for an equal time, no further change in the mechanical properties took place on extending the period of annealing to one hour. The quenched specimens were rods 1in. diam. and 8in. long, having a volume of 6·3 cub. in., and weighing about 1·6lb.; they were heated up to 900° C., kept at that temperature for about 15 minutes, and then quenched in cold water.

In view of the marked difference in properties between some of the quenched and the slowly-cooled specimens, it was thought desirable to make tests on air-cooled samples of the same dimensions as above, for which the rate of cooling was quicker than for the annealed series, though, of course, much slower than for the quenched metal. The dimensions of the finished test pieces were: Diameter, 0·564in.; gauge length, 2in.; parallel, 2¼in. The tests were carried out on a Buckton universal horizontal testing machine fitted with a Wicksteed recorder. From the autographic stress-strain diagrams thus obtained the yield points were measured. Some of the results are shown graphically in Figs. 1 to 4.

The following is a summary of the effect of nickel on the mechanical properties of these alloys: any marked discontinuity in the mechanical properties was in nearly every case found to be associated with a change in the microstructure, and this will be referred to later when dealing with the micrographic analysis of the alloys.

Aluminium, 10 per Cent.—*Chill Castings* (Fig. 1).—Increased maximum stress and yield point are obtained up to 10 per cent. of nickel at the expense of elongation and reduction of area. Above that point all the properties diminish. The

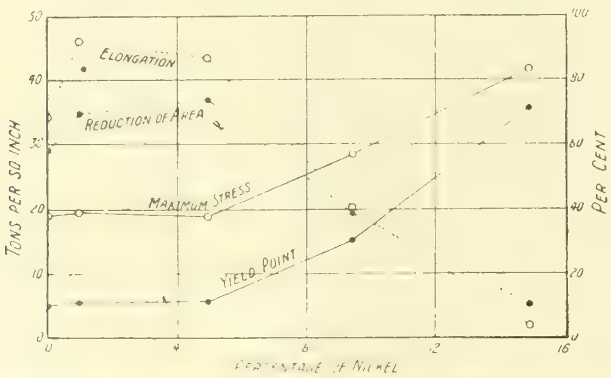


FIG. 3.—TENSILE TESTS. ALUMINIUM 5 PER CENT. CHILL CASTINGS.

10 per cent. nickel alloy in the form of chill casting is improved by annealing at 900° C.

Annealed Rods (Fig. 2).—The mechanical properties are all considerably improved by the addition of 5 per cent. of nickel. Above this figure elongation and reduction of area begin to fall off.

Cold Rolled Rods.—The only marked change which takes place with increasing percentages of nickel is a considerable rise in the maximum stress, without any reduction in ductility.

Quenched Rods.—The effect of nickel in the quenched bars is to reduce slightly the maximum stress: the elongation and reduction of area increase with the percentage of nickel, but are very small throughout.

Air-cooled Rods.—The mechanical properties were intermediate between those of the quenched and annealed series. The alloys thus treated resembled the latter series, but possessed a higher maximum stress.

Aluminium, 5 per Cent.—*Chill Castings* (Fig. 3).—Up to 5 per cent., nickel greatly improves the elongation and reduction of area of these alloys without affecting the maximum stress and yield point. With more than 5 per cent. of nickel, the latter properties are rapidly improved, while the elongation and reduction of area suffer a corresponding decrease. Nevertheless the yield point and maximum stress are both raised by about four tons per square inch, before the ductility is reduced to that of the pure copper-aluminium alloy. The increase in elongation and reduction of area due to the first 1 per cent. of nickel is very marked, the chill casting showing an elongation of 92 per cent., compared with 68 per cent. for the corresponding copper-aluminium alloy without nickel.

Annealed Rods (Fig. 4).—Here again the effect of the first 1 per cent. of nickel on the ductility of the alloy is very marked. The maximum stress and yield point rise slowly until 5 per cent. of nickel is reached, and then very rapidly to 7½ per cent. of nickel. The elongation and reduction of area begin to fall when the nickel exceeds 1 per cent., but

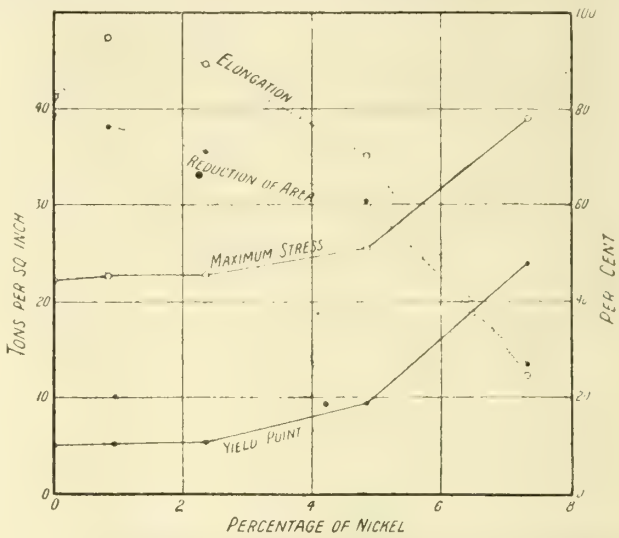


FIG. 4.—TENSILE TESTS. ALUMINIUM 5 PER CENT. ROLLED AND ANNEALED.

they still retain a very high figure even in the 5 per cent. nickel alloy.

Cold-rolled Rods.—The maximum stress and yield point are raised while the elongation and reduction of area decrease slowly with between 1 and 5 per cent., and then more quickly with over 5 per cent. of nickel.

Quenched Rods.—The effect of nickel up to 5 per cent. on the quenched material is to increase slightly the yield point and maximum stress, and to improve the ductility. Above 5 per cent. the increase in yield point and maximum stress is more rapid, and there is a corresponding fall in elongation and reduction of area.

A comparison of the results for the quenched rods with those for the annealed, showed that with less than 5 per cent. of nickel, the maximum stress is hardly affected by quenching, though the yield point is slightly raised, and the elongation and reduction of area diminished. With 5 per cent. of nickel the ductility is greatly increased by quenching, while the maximum stress and yield point are both lowered. This effect is still more marked in the alloy with 7½ per cent. of nickel, where the elongation and reduction of area are both more than doubled by quenching.

Air-cooled Rods.—Unlike the members of the series with 10 per cent. of aluminium, the air-cooled 5 per cent. aluminium alloys, containing upwards of 5 per cent. of nickel, present mechanical characteristics which approximate to those of the quenched rather than the annealed metal. The maximum stress is even slightly lower than that of the quenched material, but this is probably to be accounted for by the absence of any hardening effect due to strains set up in quenching.

Reproductions of some of the stress-strain diagrams are given in Fig. 5. The first (starting from the left) is typical

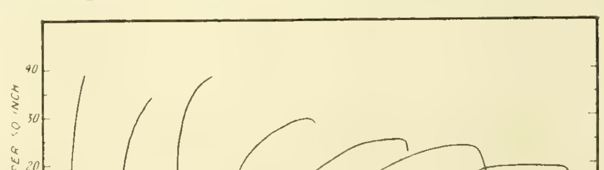


FIG. 5. STRESS-STRAIN DIAGRAMS.

of the cast metal of the 10 per cent. aluminium series with a high percentage of nickel: the next is typical of all the rolled and annealed alloys with 10 per cent. of aluminium. The four following diagrams illustrate the effect of quenching on the alloys containing 5 per cent. of aluminium, with 7½ and 5 per cent. of nickel respectively; while the last is typical of

the cast metal of the 5 per cent. series, with nickel up to 5 per cent.

Alternating Stress Tests.—The authors are indebted to Prof. Arnold for carrying out these tests on specimens of the annealed, cold rolled, and quenched rods. The results obtained under standard conditions on the Arnold machine are shown graphically in Fig. 6. The behaviour of the alloys under this test may be briefly stated as follows:

Aluminium, 10 per Cent.—The resistance of the cold-rolled rods to alternating stress is reduced by the presence of nickel. The detrimental effect which is produced by annealing the 10 per cent. aluminium alloys, and which is so well exemplified by their behaviour in this test, is to some extent diminished by the presence of 5 per cent. of nickel, a conclusion also in accordance with the results of the tensile tests. The results for the quenched rods were very irregular and untrustworthy on account of their coarsely crystalline structure, and the tendency of the test pieces to become "hinged" by the interlocking of the crystals.

Aluminium, 5 per Cent.—In each series an increasing percentage of nickel results in diminished resistance to alternating stress; in the annealed state, however, there is no decrease until the nickel exceeds 1 per cent. The effect of quenching is to increase the resistance of these alloys to alternating stress.

Hardness Tests.—The hardness of the alloys under different conditions of mechanical and heat treatment has been determined both by the Shore scleroscope (using the universal hammer) and by the Brinell method. The specimens tested were cylinders about 1in. high and 1in. diam., with polished surfaces. They were cut from the same rods as the tensile test pieces, and had received precisely the same thermal and mechanical treatment. The Brinell tests were carried out according to the standard conditions, using a 10-millimetre ball under a load of 3,000 kgs., the pressure being applied for one minute. The results given for the quenched series containing 5 per cent. of aluminium were, however, obtained with a load of 1,000 kgs.

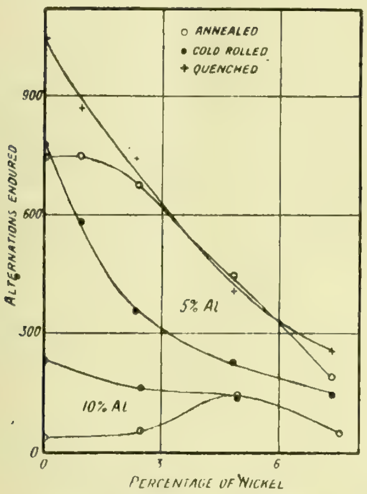


FIG. 6.—ALTERNATING TESTS.

The hardness numbers were calculated as follows:—

$$\frac{\text{Load in kilogrammes}}{\text{Spherical area of the concavity (in square millimetres).}}$$

The hardness numbers were obtained by both the scleroscope and Brinell methods. Some of the results are shown in Figs. 7 and 8, where the Brinell numbers are represented by dots and a continuous line, and the scleroscope numbers by small circles and a dotted line. The relative hardness numbers recorded by both methods are in fairly close agreement, the lines through the two sets of readings running nearly parallel to one another; but the effect of cold rolling, and especially of quenching, is greater in proportion on the scleroscope scale than in the Brinell hardness numbers

It will be seen that the hardness curves in general have the same character as those representing yield point, the most noteworthy fact being the rapid increase in the hardness of the 5 per cent. aluminium alloys in the annealed state in the presence of upwards of 5 per cent. of nickel, and in the cast state when the nickel exceeds 7½ per cent. This increase is so rapid that when the nickel reaches 7½ per cent. the annealed metal with 5 per cent. of aluminium is harder than the corresponding alloy with 10 per cent. of aluminium; and the same applies to the cast metal with 15 per cent. of nickel.

A comparison of the figures for the quenched material with those for the annealed may be made by considering the hardening capacity of the alloys, *i.e.*, the ratio of the hardness of the quenched material to that of the annealed. As the percentage of nickel increased there was a very marked and regular diminution in the hardening capacity of the alloys with 10 per cent. of aluminium. In the 5 per cent. series the value of the ratio fell below one when the nickel reached 5 per cent., and was still further reduced at 7½ per cent. of nickel, indicating that these alloys are very considerably softened by quenching, a result entirely in accordance with the tensile tests and microstructure.

Specific Gravities.—The specific gravities of the alloys as chill castings, and also as annealed, cold rolled, and quenched rods were obtained. In spite of the fact that the density of nickel

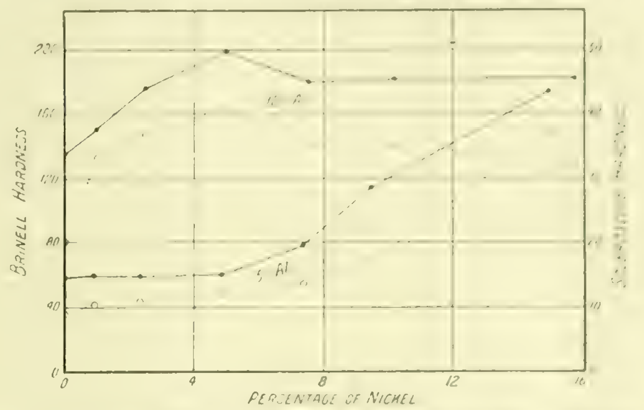


FIG. 7.—HARDNESS. BRINELL AND SCLEROSCOPE TESTS [illegible]

(8·80) is less than that of copper (8·93), it was found that the presence of nickel brought about a distinct increase in the specific gravity, this being most marked in the 10 per cent. aluminium alloy with 5 per cent. of nickel. In this series, with larger amounts of nickel, the specific gravity fell in spite of a slight decrease in aluminium. This fact, as well as the differences between the cast and annealed alloys of the same series, is probably significant in connection with the constitution of these alloys.

Melting Points.—The melting points of a number of the alloys were determined with a thermo-electric couple and a direct reading millivoltmeter. The results show that the addition of nickel to the 5 per cent. aluminium-copper alloy results in an immediate and considerable rise in the melting point; while with the 10 per cent. alloy there appears to be a slight fall at first followed by a rise before the nickel reaches 5 per cent.

Conductivity for Electricity.—The resistance of definite lengths of the wires made as described under "wire drawing" and subsequently annealed by heating to redness and cooling in air, was measured by the Wheatstone bridge method with the aid of a carefully standardised resistance box. The results are shown graphically in Fig. 9. It will be noticed that the conductivity of the 5 per cent. alloy is only very slightly greater than that of the alloy containing 10 per cent. of aluminium. The effect of nickel in both cases is to diminish the conductivity.

Corrosion Tests.—Plates of metal having the dimensions 2·0 × 0·75 × 0·1in. were tested both in the cold rolled and

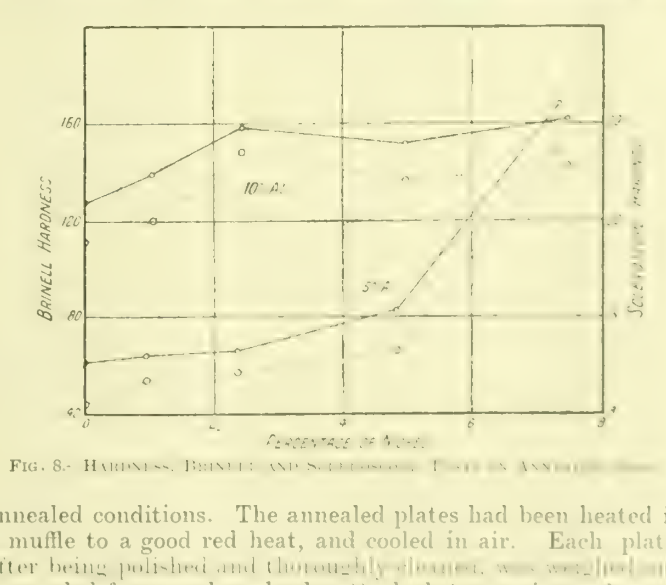


FIG. 8.—HARDNESS, BRINELL AND SCLEROSCOPE. TESTS ON ANNEALED [illegible]

annealed conditions. The annealed plates had been heated in a muffle to a good red heat, and cooled in air. Each plate, after being polished and thoroughly cleaned, was weighed and suspended from a glass hook attached to a piece of wood which rested on the edge of a porcelain tank. At the end of

the tests the plates were carefully cleaned, dried, and weighed. For purposes of comparison plates of Muntz metal (copper 61 per cent.), and of naval brass (70 : 29 : 1) were included.

Fresh Water Tests.—A gentle stream of tap water was kept flowing continuously through the tank for 144 days, during which time the plates were taken out and gently rubbed once a fortnight. The tap water was "soft" and of high quality. The results show that if the nickel has any action it is to increase the rate of corrosion. In all cases, the action of this very pure tap water on the alloys was exceedingly small. The plates were only slightly tarnished, and were all perfectly smooth. The alloys containing 1 per cent. of aluminium showed dark spots in places, the Muntz metal was more tarnished and darker in colour than any of the 10 per cent. aluminium alloys, and the naval brass was covered with brownish red patches where dezincification had begun to take place.

Sea Water Tests.—The sea water which was obtained from a bay in the Bristol Channel was changed every fortnight, and at the same time the plates were taken out and gently rubbed. The duration of the trials was 123 days. The effect of nickel up to 10 per cent. is in all cases greatly to reduce the corrosion of the alloys by the sea water, the effect of the first 1 per cent. of nickel on the 10 per cent. alloy being very marked. There was no appreciable difference in the behaviour of the annealed and cold rolled metal. The plates after their immersion in sea water were generally smooth, but varied in appearance. The pure 10 per cent. copper-aluminium alloy was much darker in colour, and the surface was roughened, while those containing nickel were quite smooth and only slightly dimmed, but had assumed a greenish tinge. The 5 per cent. aluminium alloy showed a dull reddish yellow colour, with 1 per cent. of nickel this was lighter; while the alloys with 5 and 10 per cent. of nickel respectively remained perfectly bright. The 1 per cent. aluminium alloys with low nickel were coated with a fine dark red deposit, but when the nickel reached 10 per cent. the surface assumed a dull greenish colour. Meanwhile the surface of the Muntz metal had become dimmed and covered with small reddish excrescences: and the naval brass showed a greenish deposit easily removed, leaving a reddish surface underneath.

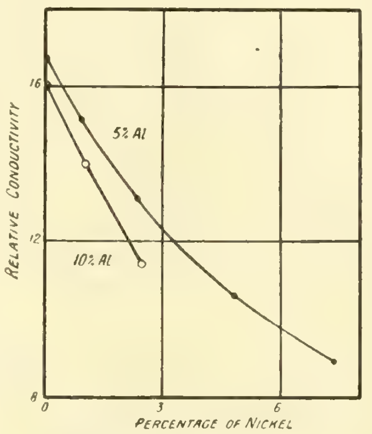


Fig. 9. Relative Conductivity for Electricity (Copper = 100).

Institute of Metals.—The report of the Council of the Institute of Metals presented at the annual general meeting recently held in London showed that the total membership now amounted to 626, an increase of 20 on the previous year's figures. The Birmingham local section had a membership of 80, an increase of 8 on the previous year. The financial statement showed that the income was £1,556. In addition there were two donations amounting to £110. The amount to be carried forward to next year's account was £699 against £563 a year ago. The ballot had resulted in the election of Engineer Vice-Admiral Sir H. J. Oram (London) as president. In his address, reproduced on page 294 of our last issue, he dealt with the splitting and corrosion of condenser tubes in the Navy. The following members of the Council were elected: Mr. L. Archbutt (Derby), Prof. A. Barr (Glasgow), Messrs. T. A. Bayliss (King's Norton), G. T. Beilby (Glasgow), A. Cleghorn (Glasgow), George Hughes (Norwich), R. E. Hutton (Sheffield), W. Murray Morrison (London), the Hon. Sir C. A. Parsons (Newcastle-on-Tyne), Arnold Philip (Portsmouth), W. Rosenhaim (Teddington), A. E. Seaton (London), Sir W. E. Smith (London), L. Summer (Manchester), and G. H. Wilson (Sheffield). A list of new members was submitted to the meeting, bringing the total membership to 640.

THE CHEMICAL AND MECHANICAL RELATIONS OF IRON, TUNGSTEN, AND CARBON, AND OF IRON, NICKEL, AND CARBON.

A paper on this subject by Prof. J. O. Arnold, F.R.S., and Prof. A. A. Read, F.I.C., was read at a meeting of the Institution of Mechanical Engineers, held in London on March 20th. The paper embodied the results of research work carried on at the University of Sheffield. The authors first described the results of tests on a series of tungsten steels. The steels were manufactured in the ordinary way in the experimental steel works of Sheffield University by the white crucible process with coke fuel. The materials used were Swedish bar iron, charcoal, and metallic tungsten. The ingots, weighing about 40lbs. each, were cast into 2¾in. square moulds and were forged into 1in. round bars. A consideration of the results indicated that in many cases practically the total amount of carbon in the steel was obtained. In some cases the slightly lower results were partly accounted for by a slight roughness of the bars, which prevented the last traces of carbide being recovered. In the steel containing 0·7 per cent. of carbon and 9·74 per cent. of tungsten, nearly the whole of the iron carbide disappeared, being replaced by a carbide of tungsten corresponding closely to the formula WC, which theoretically should contain tungsten 93·88 and carbon 6·12 per cent. Other results strongly suggested that with about 11½ per cent. of tungsten present Fe_3C could not exist. Curiously enough this percentage corresponded to the low tungsten limit for modern high-speed steels.

Passing on to the steels containing 14·96, 21·15, and 26·29 per cent. of tungsten, the authors noticed that as the tungsten rose the carbon fell and the iron rose. This fall in carbon, the reappearance of the iron in the carbide residue, and the remarkable increase in the weight of the residue yielded, at once led the authors to suspect the presence in the carbide of tungsten of a stable tungstide of iron. Numerous experiments with various reagents were made to try and separate this tungstide of iron from the carbide, but without success. The results obtained by increasing either the strength of the hydrochloric acid or the current density showed that the only effect was to reduce the percentage of total carbon obtained in the residue, without altering the composition of the latter.

In crucible steel-melting operations at Sheffield University, which had for their object the preparation of ferro-tungsten, the existence of tungstide of iron raised difficulties on account of its high specific gravity, which rendered the preparation of a homogeneous alloy almost impossible in the crucible. In making very pure 40 to 50 per cent. ferro-tungsten, from metallic tungsten and Swedish bar iron, there was always a fluid portion which teemed easily, and a liquated portion at the bottom of the crucible which it was almost impossible to pour owing to its higher freezing point. It remained in the crucible in a pasty condition, and when cold was drilled with difficulty by a special drill which easily drilled the hardest chilled white iron. Therefore its hardness approximated to that of felspar, namely, 6 on Möh's mineral scale. A table was given containing an example of this phenomenon. The fluid and relatively low freezing-point alloy contained 38·2 per cent. tungsten and weighed 14½lbs. The higher freezing-point metal, which would not pour, contained 52·3 per cent. tungsten and weighed 13lbs. The composition of the higher freezing-point metal approximated to Fe_3W. This unavoidable liquation rendered it impossible for a big bar of high-speed steel (made, say, from a 2-ton ingot) to be homogeneous. The tungsten at the bottom of the ingot was always distinctly higher than that at the top, and the higher the tungsten the more pronounced was the difference between the top and the bottom of the bar.

The micrographic analysis of the tungsten steels had revealed the presence of three new constituents: (a) tungsten pearlite, (b) tungsten cementite, and (c) tungsten hardenite. Tungsten pearlite seemed to present only the sorbitic variety of pearlite, namely, finely granular or minutely laminated. As in the case of vanadium pearlite, the authors had not yet been able to determine exactly the carbon saturation point. Tungsten cementite had been obtained on annealing the high tungsten alloys in nodules resembling iron cemen-

tite, as the result of the segregation of the WC of sorbitic tungsten pearlite. Tungsten hardenite formed from tungsten pearlite progressively and slowly, the transformation beginning about 850° C. (1,562° Fah.), apparently being completed at about 1,150° C. (2,102° Fah.). This steel contained 14·96 per cent. of tungsten and 0·73 per cent. of carbon. The accompanying table gives a somewhat crude but nevertheless decisive practical proof of the progressive formation of tungsten hardenite from its pearlite.

Steel No.	Tungsten.	Carbon.	Water quenching temperatures.	File test indications.
	Per cent.	Per cent.	Deg. C.	
1243	14·96	0·70	860	Filed easily.
1245	21·15	0·73	860	Filed easily.
1243	14·96	0·70	1,000	Hard, but could be filed.
1245	21·15	0·73	1,000	Hard, but could be filed.
1243	14·96	0·70	1,100	Would not file.
1245	21·15	0·73	1,100	Would not file.
1243	14·96	0·70	1,190	Very hard, stripped file.
1245	21·15	0·73	1,190	Very hard, stripped file.

The above results were obtained by heating the steels in a bath of barium chloride and then quenching in cold water. The temperatures were electrically adjusted, read off by means of a thermo-couple pyrometer, and were accurate to within 10° C. The quenching test pieces employed were all in the form of discs ⅞in. diam. and ¼in. thick. The facts shown in the above table had been (in connection with tungsten self-hardening steels) known to practical men for at least 20 years, as evidenced by a card of instruction issued by a British firm in 1893 and produced in the great American high-speed steel lawsuit on August 6, 1907.

For working special self-hardening steel the steel must be heated very gradually; if worked at too low a heat it was liable to crack. The steel must be heated several inches higher up than was required to be forged. After forging the tool should be re-heated to a reddish-white heat and then allowed to cool gradually in a dry place. By varying the heat from a dark cherry-red to a reddish-white the various tempers for all tools could be readily obtained.

In summing up this portion of the paper the authors said: "It will be evident that in some respects the role of tungsten in steel somewhat resembles that of vanadium, but its action is much less marked. Its points of resemblance are: (1) It forms no double carbide; (2) it entirely displaces Fe_3C, but whilst vanadium effects this displacement when only about 5 per cent. vanadium is present, it requires about 11 per cent. of tungsten to completely expel the carbide of iron; (3) high tungsten accelerates the segregation of the carbide of tungsten in sorbitic tungsten pearlite into tungsten cementite, just as high vanadium hastens the segregation of the V_4C_3 of sorbitic vanadium pearlite into vanadium cementite. The points of difference are: (a) Vanadium pearlite (like iron pearlite) transforms with a marked thermal abruptness (say, over an amplitude of a few degrees) into vanadium hardenite at about 1,400° C. (2,552° Fah.), but the transformation of tungsten pearlite into tungsten hardenite spreads over the very wide amplitude of, say, 300° C. before completion; (b) the authors have obtained no experimental evidence that tungsten, like vanadium, is capable of forming tungsten troostitic pearlite."

Turning to the question of nickels the authors explained their efforts to isolate nickel carbide. They decided to cast a series of 1⅛in. round bars, cool as quickly as possible in air, and turn the carbide bars from the alloys as cast. This method was to a great extent successful, since in a steel containing about 0·7 per cent. carbon and 30 per cent. nickel the maximum percentage, namely, 0·13 per cent. of graphite, was precipitated.

Considering the carbide results, they said that with steels fairly high in carbon, and containing up to 8 per cent. of nickel, the carbide Ni_3C existed only in negligible proportions. The cast bar calculated to contain 0·55 per cent. of carbon and 13 per cent. of nickel was so hard as to defy both hacksaw and turning tool. With carbon about 0·8 per cent. associated with from 20 to 30 per cent. of nickel the Ni_3C had obviously assumed the supremacy. The obvious conclusion from the results was that in ordinary (necessarily somewhat manganiferous) structural steels containing nickel, say, up to 7 per cent., the nickel was not associated with the carbon, but was alloyed with the iron and manganese. This fact seemed to explain the somewhat distinguished position held in steel metallurgy by "nickel chrome" steels. The chromium was essentially an element exerting its influence as a carbide or hardening constituent, whilst the nickel also present was an element modifying solely the properties of the ferrite by producing in it an augmented elasticity without seriously diminishing its ductility. The question arose in what definite proportions did iron and nickel alloy produce a specific compound or solid solution?

The authors were of opinion that there was a definite alloy of iron and nickel corresponding to the formula Fe Ni, and that this substance was perhaps the most remarkable known to ferrous metallurgy. They arrived at this conclusion as the result of some experiments made on the suggestion of Sir Robert Hadfield in 1898. A set of alloys of nearly pure iron and nickel were made, all the ingots hammered and rolled quite soundly, being evidently practically free from dissolved oxygen. A table was presented, showing the results of chemical and mechanical tests of this alloy. Attention was called to the surprising ductibility, namely, 11 per cent elongation, 46 per cent. reduction of area, and a bending angle of 167°, associated at 13 per cent. of nickel with a yield point of 59 tons and a maximum stress of 88 tons per square inch. The stiffness of the alloy when as a ½in. diam. bar it was bent over by repeated blows from a sledge hammer, was more than remarkable. Nearly pure iron containing 7 per cent. of nickel had nearly the same mechanical properties as iron containing about 33·5 per cent. of nickel, namely, a yield point of about 30, and a maximum stress of about 38·5 tons per square inch, associated with an elongation on 2in. of about 30, and a reduction of area of about 57 per cent.

In conclusion, the authors remarked that nickel agreed with all the other elements, the carbides of which they had investigated, in being a law unto itself. It was true that there was some resemblance between the properties of nickel and manganese, but in their mechanical influences on iron, they were often strangely dissimilar. Theoretical metallurgists seemed to lose sight of the fact that the final verdict on their theories must be pronounced by the engineer, who puts them to the stern and implacable tests of mechanical practice.

British Warships and their Cost.—A Parliamentary paper recently issued gives particulars of the cost and maintenance of a number of warships. At the head of the list given, so far as cost of construction is concerned, appears the "Valiant" £2,356,133, others in order being the "Barham" £2,348,078, the "Warspite" £2,325,328, and the "Queen Elizabeth" £2,314,762. The cost of these four men of war was increased about 12 per cent. by a rise in prices. Another £2,000,000 sterling warship is the "Tiger." The total estimated average annual cost of maintenance of the four ships above mentioned is £170,410 in each case, that of the "Tiger" being given as even more, £183,680.

Institution of Mining and Metallurgy.—The twenty-third annual general meeting of this institution was held in London on March 26th. The retiring president, Mr. B. McNeill, occupied the chair. In the report of council presented it was shown that the institution had made substantial progress in all directions. The gold medal presented by the Consolidated Goldfields of South Africa was awarded conjointly to Messrs. A. J. Clark and William J. Sharwood for their paper on "The Metallurgy of the Homestake Ore," and the premium of 40 guineas went to Mr. L. H. Cooke for his papers dealing with "Precision Theodolites." The William Frecheville students' prize of 10 guineas was awarded to Mr. P. L. Teed for his paper on "The Determination of Water in Coal," and post-graduate scholarships of £50 were allocated to Messrs. Lake (London), Scott (Birmingham), Goepel (Camborne), and Thomas Robertson, B.Sc., graduate of Heriot Watt College. After the presentation of the awards the newly elected president, Dr. F. H. Hatch, took the chair and delivered his presidential address.

RELATIVE COST OF COKE, OIL, AND GAS FOR MELTING NON-FERROUS METALS.

Some tests have been made at the Sheffield University to ascertain the relative merits of coke, oil, and gas as fuels for melting non-ferrous metals, the results of which were recently published by Prof. J. O. Arnold. The results, which are given in the accompanying table, are based on a run of 14 hours, involving an aggregate weight of brass of nearly one ton, and show a strong primâ facie case for the use of gas as a fuel for melting non-ferrous metals. It will be noted from the figures given in the table that the cost of gas per 100lbs. melt was 2·9d. lower than that of coke. This is due to the special advantage the city enjoys from the low price of gas. The cost of oil renders the use of this form of fuel prohibitive, though it possesses an outstanding value for the purity of the product as regards sulphur. The question of oxidation has not yet been dealt with, but experiments are being put forward whereby the relative merits of the three systems of melting in this particular will be established. The coke furnace is of the ordinary type found in local shops, having a capacity for 90lb. pots; the oil furnace is of similar capacity, the air being under a pressure of about ¾lb. per square inch; the gas furnace has a capacity of 70lb. pots. With regard to the gas and oil furnaces, it is pointed out that the smaller pot used for 30lbs. does not give the maximum good result possible to be obtained, as a certain amount of heat is wasted in using the smaller pots.

	Coke.	Oil.	Gas.
Output on 14-hour run (total 2,220lbs. brass)	720lb.	750lb. *a*	750lb. *a*
Weight of charge	30lb.	30lb.	30lb.
Number of casts	24	25 *b*	25 *b*
Time taken for melting initial 30lb. charge, starting cold furnace	89min.	70min. *c*	78min.
Time taken for melting subsequent charges, minimum	22min.	20min.	19min. *d*
Time taken for melting subsequent charges, maximum	37min.	41min.	34min.
Time taken for melting subsequent charges, average	29min.	29min.	27min.
Fuel, Cost of	24 per ton.	80 – per ton.	10d. per 1,000 cu. ft.
Fuel (Heat value) British Thermal units	12,960 per lb.	19,700 per lb.	570 per cu. ft.
Consumption of fuel per 100lbs. brass melted	66lbs.	4·1 gall.	383 cu. ft.
Cost of fuel per 100lbs. brass casting	8·6d.	15·3d.	3·8d.
Electrical energy for blast at 1d. per unit	Nil	3·3d.	1·1d.
Cost of graphite crucibles (on a basis of a 48 heat life)	2·5d.	3·3d.	3·3d.
Total cost of melting 100lbs. brass	11·1d.	21·9d.	8·2d. *e*
Zinc loss on 100lbs. brass	0.40% *f*	0·85%	0·44%
Sulphur (absorbed from fuel) per cent. per cast	0·0040	0·0010 *g*	0·0026

a. Oil and gas, although working to a disadvantage in the small charges used, secured greater outputs.

b. These, with increased facilities, would probably have reached 27.

c. The heating from "dead cold" to first cast shows an advantage to the oil furnace.

d. Gas shows the lowest minimum for any 30lb. charge, viz., 19 minutes from charging to pouring.

e. This shows a distinct saving in favour of gas; the relation being—Gas 100, coke 135, oil 267.

f. Coke melting, with special care, shows the lowest zinc loss (0·4 per cent.).

g. Oil melting yielded the purest product (sulphur content). This would vary with the type of oil used.

The Institution of Automobile Engineers.—Colonel H. C. L. Holden, F.R.S., has been elected president of this Institution for the forthcoming session, while Messrs. Max Lawrence, Mervyn O'Gorman, and Alex. Craig will be the vice-presidents. As a result of the ballot for vacancies on the Council, Messrs. Thos. Clarkson (Chelmsford) and A. A. Remington (Birmingham) have been added to that body.

THE DESIGN OF ROLLING STOCK FOR ELECTRIC RAILWAYS.*

BY H. E. O'BRIEN.

It is now a well known fact that the possibility of the application of electric traction proving remunerative depends on the density of the traffic plus the possibilities of development; in other words, the larger the number of stations per mile the greater is the probability that electric working will result in a reasonable return being obtained on the capital expended. It must also be remembered that on railway systems embracing several large towns the suburban and interurban passenger mileage is a very large percentage of the total passenger-train mileage. In the more densely populated parts of England the train mileage on lines of railway companies which have sufficiently heavy suburban traffic to make electrification worth considering is probably not less than 20 per cent. of the total passenger-train mileage. Railways engaging in electrification of large suburban areas therefore find that the cost of operation of the electrical services is an important proportion of their total expenditure; and, bearing in mind the large addition to their original capital expenditure involved by electrification, every means of reducing both the capital cost and the cost of operation becomes a matter of serious importance and worth the minutest investigation. The whole cost of electrification and of subsequent operation will depend on three factors: (1) the number of stops per mile; (2) the schedule speed of the trains; (3) the weight of the trains.

Factor (1) is fixed by the nature of the district. Factor

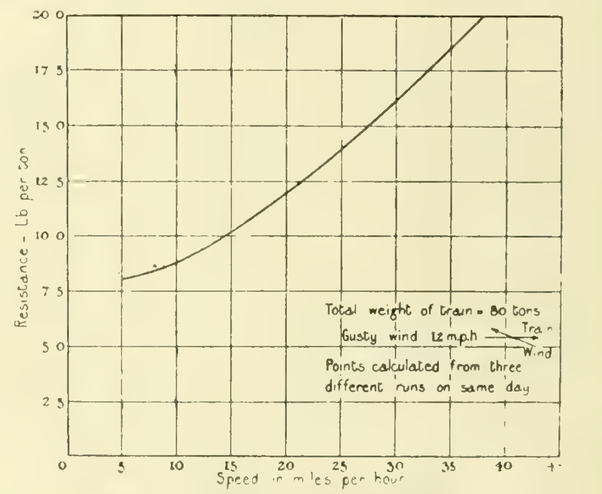


Fig. 1.—Resistance of Two-car Train.

(2) is a matter for determination by the management: the needs of the population of one district can only be served by a very fast service, while in another district a slower schedule with more frequent trains will attract just as much traffic. If the train equipments had to be designed for lines with stations placed at uniform distances apart, and on a level track, the problem of securing the most economical motor and control would be comparatively simple. But it will often happen that a profitable electrification will involve runs with very short distances between the stops in the vicinity of a large town, and also runs with much longer distances between the stops as the trains get farther from the urban area; and very possibly at the extremity of the electrification a secondary urban area is approached necessitating a number of stops in close proximity to each other.

The most remunerative traffic will be that between the extremities of the electrification, between the primary and secondary urban areas; consequently the equipments will have to be designed so as to make a journey of this length a reasonable one. Expresses as well as stopping trains will be required (as has been found on the London Underground Railways), and as in most cases the setting aside of special stock for express services would involve extra capital expenditure, a compromise has to be accepted both in the motor characteristic and in the gear ratio. The equipments would normally be of such a character as to permit of a fairly large percentage of coasting on the longer runs for maximum economy, but the commercial management will soon realise

* Abstract of paper read before the Institution of Electrical Engineers.

that time can be saved by maintaining full speed nearly as far as the stopping points in these cases; also, as the district develops, extra stations will be introduced, which will make the original gear ratios incorrect. In consequence the equipments will normally run in such a way as to require a high energy consumption. This energy consumption is the sum of that wasted in the resistances and motors, of that wasted in the brakes, and of that utilised in overcoming train resistance. The first two of these losses are directly proportional to the weight, and the third—the train resistance—is so nearly proportional to the train weight that it may be taken as being so for practical purposes. Fig. 1 shows the resistance of the Lancashire and Yorkshire Railway Company's trains as actually obtained by the coasting method.

Fig. 2 shows the approximate division of the total energy between its various components. The curve in Fig. 3 shows the percentage of the whole used for acceleration for runs of half a mile and upwards. The schedule speed is maintained constant by prolonging the coasting period for the longer runs. This curve emphasizes the enormous importance of light rolling stock, as far as the influence on the energy consumption of the trains on high-schedule short-distance suburban services is concerned. It will be seen that the energy consumed varies almost directly as the weight of the trains, although for runs between stations less than one mile apart the importance of the acceleration component increases as the distance decreases. High energy consumptions per ton are likely to accompany commercially successful electrifications, and the sole variable factor that can be attacked, and which enormously influences the whole problem, is the weight of the rolling stock. It is therefore very important to consider in detail how rolling stock may be built so as to give a maximum value to the ratio—number of seats provided per ton weight of train. The fact that the coaches must be comfortable must not be lost sight of; but there is no need to assume that light coaches are uncomfortable to ride in. Excellence in riding is obtained by the use of bogies of the maximum wheelbase permissible, and by careful design of the seating and springing systems; also by concentration of the motor masses as near the bogie centre and as high as possible. The necessary protection against the possible effects of collision and fire must be provided, but such protection is not necessarily obtained by extra weight.

Non-inflammability has hitherto been secured by the extensive use of steel instead of wood, but there is no reason why a lighter metal should not be used. Lightness of construction may be obtained either by using reduced scantlings, which is undesirable as involving a reduction in the factor of safety, or by using lighter materials, or by using materials of greater intrinsic strength, thus enabling the scantlings to be reduced without sacrificing the strength of the whole structure. Unfortunately it is necessary to buy more costly materials in order to combine strength with lightness; some of the lightest and strongest materials are still very costly, one proprietary article exceedingly suitable for rolling stock construction costing over £300 per ton. It is necessary at this point to consider to what extent increased capital expenditure is justified by the saving effected in running expenses. Assuming 100 watt-hours per ton-mile at the ends of the high-tension feeders as a typical energy consumption in the near future, and 60,000 miles per annum as a probable mileage per car per annum, then every ton of motor-car involves a consumption of 6,000 kilowatt-hours per annum. This is equivalent to an annual expenditure of £12·5 per annum per ton for energy if a total cost of 0·5d. per unit is assumed. It is recognised that with centralised power distribution a lower selling cost than this is attainable, but except on the North-east Coast it is hardly probable that electricity could either be bought from companies or corporations or produced by railway companies themselves at a cheaper rate. Unfortunately the evening railway peak coincides with the winter tramway and lighting peak in large towns, thus militating against a reasonably cheap supply. Production by a railway company has the advantage that no selling or advertising charges, or charges involved in laying mains in streets, have to be borne. Further, the operation of a generating station and sub-stations falls naturally within the province of the Chief Mechanical Engineer's Department, and not only is the highest efficiency obtained, but also management charges are reduced to a minimum, and the mischievous changes of policy that occur with municipal stations are avoided.

The cost of repairs to each ton of rolling stock will amount to about £5 per annum for a high-speed service; and its passage over the rails will probably involve repairs to the track equivalent to another £1 per annum, or a total cost per ton of motor-car of £18·5 per annum. On similar lines the cost per ton of trailer-car will be about £14·5 per annum, the energy charge remaining constant and the other charges being smaller. The capital cost per ton of motor-car will be approximately £70, and per ton of trailer £45. Hence every ton of weight saved represents (taking interest and depreciation on capital at 10 per cent.) a total saving per annum of £25·5 per ton of motor-car and £19 per trailer-car per ton per annum. It becomes therefore a commercial proposition to spend as much as £185 per motor and £145 per trailer in labour and material in order to save a ton in weight on the particular service chosen for this illustration, or, in other words, every pound of weight saved produces an economy of about 2d. per annum, or is equivalent to securing one additional passenger per annum in perpetuity.

But further considerations of capital expenditure are involved. Every ton of coach involves a consumption of 6,000 kilowatt-hours per annum, and plant has to be provided to produce this energy. It will be observed in Fig. 4 that the maximum demand for energy acceleration is exactly proportional to the weight of the train. The capital expenditure in small or medium systems does not decrease directly as the weight of the train, but is affected by the ratio of the maximum load to the mean load. After a certain point the capital expenditure per ton of train will decrease owing to

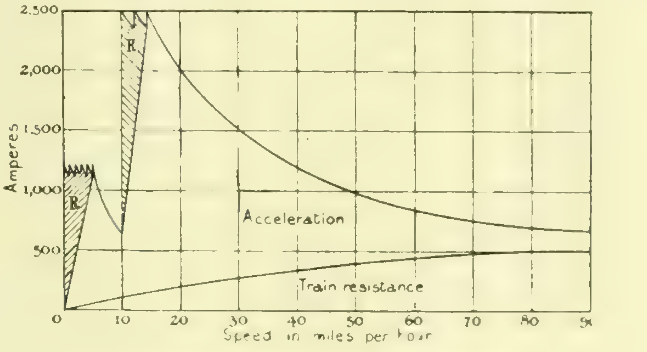


FIG. 2. TYPICAL CURVES SHOWING ENERGY LOSSES.

the reduced cost per kilowatt of the power house and sub-stations, but not sufficiently to affect in any marked way the arguments advanced in this paper. In a plant supplying an infinite number of trains the maximum and mean loads would be the same, and in a plant supplying only one train the ratio would be approximately three to one. An average plant carries about 50 per cent. overload momentarily, and consequently the cost of the turbines, generators, rotary converters, and transformers will be more than increased proportionately to the weight in any system carrying less than about 14 trains, as shown in Fig. 4. Hence the smaller the system and the severer the schedule the more important is the weight of the train.

In designing cars to give a maximum seating capacity for a minimum weight a careful investigation of the maximum possible width is the first essential, because extra seats can be given by extra width with a smaller increase in weight rather than by extra length: in many cases extensive slewing of tracks will be justifiable if practicable where structural alterations to the platform are not too expensive, or where tunnels do not prohibit this. The length of the coach will be determined by the throw of the coach, the versed sine of the worst curves on which trains will pass each other, and the minimum width between the tracks at that point. With corridor coaches, or side-door coaches with doors opening inwards, or sliding doors, a very small clearance can be adopted with safety. The ventilation of the cars has considerable influence on the energy consumption of the coaches, because the heating load becomes very appreciable in cold weather. On interurban railways in the English climate it may be estimated that there will be at least an increase of 9 per cent. in the load in the winter months due to heating

only. It is most important to secure a minimum weight for the heating equipment, and it would pay so to arrange it that it could be entirely removed when not required.

Having decided on the maximum length and width permissible for the body, it is important to consider further the directions in which weight can be saved in this part of the coach, as this has a very direct influence on the total weight. A light body with weights distributed to the best advantage permits the use of a lighter underframe, and this in its turn reduces the rated horse-power of the motors for a given schedule. The reduction in the rated horse-power of the motors permits of lighter bogie scantlings, and also in many

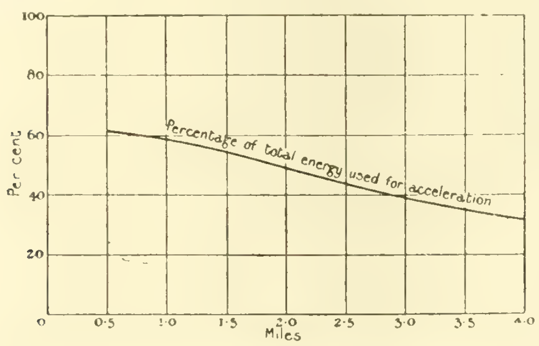


FIG. 3.—CURVE SHOWING PERCENTAGE OF ENERGY USED FOR ACCELERATION FOR RUNS OF HALF-MILE AND UPWARDS.

cases of a lighter design of control apparatus. The influence of the weight of the body is therefore progressive throughout the whole car, and for every ton of weight saved in the body it is probable that another ton can be saved in the bogies and motors. Very little difference is made in the weight by the use of any material other than wood for the roof sticks and pillars. It would appear that there is little object in using steel for the pillars, as some of the Australian hard woods are practically as non-inflammable as metal, when the scantlings used are not too small. For the actual outside roof, wood, steel, or aluminium can be used. There is practically no difference between the weight of the roofing in a wood or aluminium roof, but approximately half a ton in weight can be saved on a 60ft. car by the use of an aluminium roof instead of a steel roof. Aluminium, in addition to its extremely light weight, has the advantage of being non-corrodible, and therefore requires very much less painting than either steel or wood. The main difficulty that has been encountered by the use of aluminium is the erosion of the holes where screws or nails are put through the plates to secure them. If the coach, however, is properly constructed and the movement of the structure is not too great, this is not of much consequence. By the use of aluminium for the outside panels a saving of nearly half a ton can again be effected as compared with steel. The comparative weights and cost of various panelling materials are as follows:—

		£	s.	d.
426 sq. ft. steel panelling 18 W.G. at 1·95lbs. per sq. ft.	830·7lbs.	3	9	9
426 sq. ft. baywood panelling ⅜in. thick at 1lb. per sq. ft.	426lbs.	10	6	4
426 sq. ft. aluminium panelling 16 W.G. at 0·88lb. per sq. ft.	375lbs.	18	4	2
426 sq. ft. 4-ply panelling $\frac{5}{16}$in. thick at 1·06lbs. per sq. ft.	452lbs.	16	17	6

The weight of the glass in a modern coach is a very considerable item, amounting to 7 cwts., or 1·4 per cent. of the weight of the whole coach. Wood has very commonly been used in the construction of the floor. It would seem probable that the floor of the future would consist of corrugated aluminium plates filled in with some form of composition, such as treated cork, to a sufficient depth to cover the crests of the corrugations by about ¼in. The design of the underframe depends largely upon the weight of the body and upon the size of the motors and the motor bogies. It is very important that the motors should not be so large as to come up within the framing of the motor-car, as it then becomes very difficult to introduce the necessary diagonal bracing in the vicinity of the bogie centre. If this diagonal bracing is to be omitted the sole bars have to be made of a correspondingly thicker section, thus increasing the weight. Up to now the use of a high-tensile steel has not been sufficiently considered in the construction of underframes; such steels have been extensively used in motor-car construction and in bridge building. So far as the author is aware they have not been applied to electric rolling stock. The usual structural steel is that which complies with the British Standard Specification No. 17A, having a breaking strength of 28 to 32 tons per square inch, with an elongation of not less than 20 per cent. The relative strengths of this steel and two alloy steels used at present in motor-car construction, but equally available for electric rolling stock, are as follows:—

Steel.	Maximum Stress. Tons per sq. in.	Elastic Limit. Tons per sq. in.	Elongation on 2in. Per cent.	Reduction of Area. Per cent.
Nickel* 3%, C 0·2% ...	30	19	31	31
Vanadium 0·27%, C 0·2%	44	33	19	41
British Standard Specification for carriage underframe	30	14	20	50

* Rolled plate.

These steels are nearly twice as strong as a steel usually employed to-day, and in consequence the scantlings can be reduced by at least 25 per cent. in area, with a corresponding reduction in weight. The weight of an underframe for a 60ft. trailer coach is approximately 5 tons. Nearly a ton of this weight might be saved by the use of suitable material. It is recognised that alloy steels are more expensive and are slightly more difficult to roll, but there should not be more than 100 per cent. increase in cost per ton of material, while the labour involved in erection would of course be less. As the first cost of underframe material is low and will never exceed more than £7. 10s. per ton, any saving in weight made by the use of more expensive material will easily pay for itself.

The disposition of the weights of the apparatus attached to the underframe has a considerable effect on its design; and the weight per foot-run, and the brake, resistances, and control apparatus of the motor-cars should be distributed as far as possible along the length of the body, even if it involves some slight increase in the cost of cabling. In order further to reduce the weight of the body, the use of aluminium cable should be considered, though the difficulty in jointing introduces a serious fire risk, and in many cases renders its use inadvisable; and in connection with the contactors, wherever it is possible to use bar connections aluminium bar should be used rather than copper, and wherever castings are subjected to light stresses aluminium castings should be used.

The bogies generally may be divided into two broad classes, those arranged with equalising beams between the axles, and those built on the lines of the ordinary English

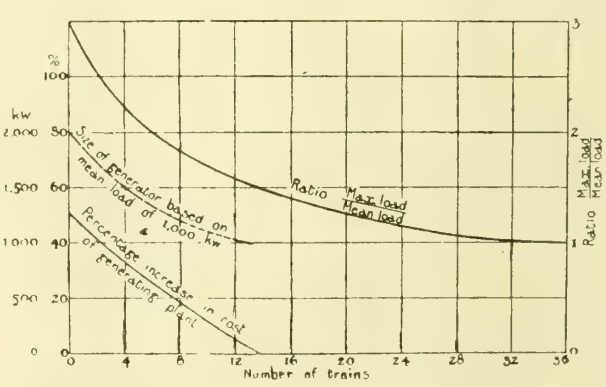


FIG. 1.—INFLUENCE OF NUMBER OF TRAINS UPON CAPITAL COST.

carriage bogie. The equalising type of bogie is always the heaviest type, and is quite unsuitable for English railways with their excellent permanent way. The ordinary type of bogie used for carriages on the steam railways of this country may be built with elliptical or spiral bolster springs, either outside or inside the wheels. There is a considerable advantage in putting the springs inside the frames, as this enables the bolster to be made wider and the bolster spring to be put farther away from the centre pin of the bogie, thus tending to diminish rolling. There is a considerable saving by using spiral bolster springs instead of elliptical bolster springs;

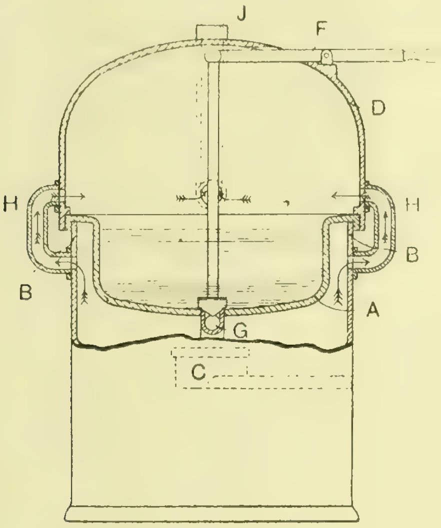
nearly 0·75 ton per coach can be saved in this way. In the author's experience elliptical bolster springs are quite unnecessary for the purpose of steady riding. The best results are obtained by having short, stiff, semi-elliptical springs over the axle boxes with assistant helical springs at their ends.

The wide frame involves an increase in weight; but on account of the steadier riding obtained by the wider centres of the bolster springs it is worth having. Cast iron is very usually used for axle boxes, but cast-steel axle boxes and cast-steel axle box slides will enable the weight of these parts to be reduced by 22 per cent.

In connection with the weight it is very important to consider the arrangement of brake blocks. It is very usual in modern designs to arrange for blocks to press on either side of the wheels with a view to eliminating the stresses due to a one-sided application of the brake. The double brake block arrangement involves, however, a very considerable increase in weight, amounting to nearly one ton per coach. The increased stresses, however, will mean increased diameter of the axles, increased bosses on the wheels, and an increase in the size of the motor housings, which will amount to a greater weight than that saved by the single brake block arrangement.

HALL'S FURNACE FOR MELTING METALS.

The accompanying illustration shows a sectional view of a furnace adapted for the melting of used metal, cleansing it and casting it into ingots, the invention of Mr. Isaiah Hall, Exchange Buildings, New Street, Birmingham. To minimise



Hall's Metal-melting Furnace.

oxidation of the surface of the molten metal the combustion chamber arranged beneath the melting pot is connected to the space above the melting pot by pipes so arranged in combination with a flue that the products of combustion are passed continually over the whole surface of the molten metal in the pot. Referring to the cut, the melting pot A is supported upon the casing B, completely enclosing the upper end so as to form a chamber in which is disposed the gas burner C. Over the melting pot is disposed the dome-shaped cover D forming a second chamber above the surface of the metal. The metal is charged through a door disposed in this cover D, and there is also an arm F arranged to regulate the flow of the molten metal to the pouring spout G. Connecting pipes H are shown leading from the chamber in which the gas burner is located to the chamber above the pot, the flue J being disposed at still another point upon the cover, both the pipes H and flue J being disposed close above the surface of the molten metal at equal intervals around its periphery. In this manner products of combustion are passed into the periphery of the pot and drawn over the surface of the molten metal on their way to the flue, and any air which passes into the chamber will either be drawn direct to the flue or will form an inconsiderable proportion of the total quantity of gas in contact with the surface of the metal.

ELECTRIC BATTERY VEHICLES.*

This importance to the central station of the load to be obtained by a general use of electric vehicles can hardly be over-rated. It is in practically all cases an "off peak" load, and as it will in nearly all cases come on during the night, when the majority of the other consumers have ceased to make any demand on the supply, it will have a tendency to flatten out the generating station load curve in a most favourable manner. Every central-station engineer knows the beneficial effect that such an improvement in the station load factor will have upon the cost of generation, rendering it possible to reduce the selling price to all consumers, and, by the increased demand thereby created, greatly benefiting the electrical industry generally. Little wonder, therefore, that the central-station engineer, now fully appreciating these possibilities, is keen on doing all that he can to popularise the electric vehicle and to facilitate its adoption. At the moment, the most promising opening for the electric vehicle appears to lie in its use for commercial purposes; but it is by no means improbable that the passenger-carrying vehicle, whether for business or pleasure purposes, will not eventually be considered from the central-station point of view almost as important as the commercial type of vehicle.

One frequently meets people—some of whom, unfortunately, are engineers—who, at the mere mention of an electrically-driven vehicle deriving its energy from a storage battery, grow sceptical, openly expressing their doubts as to the possibility of such a method of road traction ever proving commercially successful. They apparently base their opinions upon the failures of past years. It cannot be too strongly emphasized, however, that the electric vehicle of to-day is not to be judged by the experiences of even a few years ago in this country. Since that time great advances have been made in storage battery construction, the design of the motors for electric vehicles has been improved, ball and roller bearings have been brought to a high pitch of perfection, chassis construction has been lightened, and better and more efficient rubber tyres can be obtained. For the improvements in the latter three items, the electric vehicle owes much to the wonderful evolution of the petrol car in the past few years.

The proper sphere of utility for the electric vehicle at the present time is undoubtedly in inter-urban and suburban districts where its mileage limit per charge is not a drawback. The passenger-carrying vehicles and the lighter pattern of commercial vehicles are generally capable of doing from 50 to 60 miles per charge, and it will be found that in most cases this covers the daily requirements for work in such districts as those mentioned. By a boosting charge during the driver's dinner-hour, the daily mileage capacity may be appreciably increased. The utility of the electric vehicle in inter-urban and suburban areas is amply demonstrated by the number of vehicles in daily use in the United States alone. At the present time there are over 37,000 electric vehicles in use in that country, of which more than half are passenger-carrying machines used for business or pleasure purposes. There are said to be about 40 firms engaged in constructing these vehicles in America, and the number of such vehicles is increasing at a rapid rate. In certain cities on the European Continent, also, this type of automobile is rapidly coming into general use, and hundreds are already running and giving satisfactory and economical service.

If we have to admit that there are limits to the scope of usefulness of the electric vehicle; if we have to concede to the petrol vehicle, as we certainly must, some of the merits that it is known to possess; if we must agree that there are certain fields that the latter will probably continue for some time to hold as pre-eminently its own; it is nevertheless true that within its own legitimate sphere the electric vehicle can show a degree of economy, and a record for reliability, with which no other existing type of vehicle can hope to compete. We shall, I think, be wise if we

* Abstract of discussion by F. Ayton before the Institution of Electrical Engineers, March 19th, 1914.

frankly admit the probability that each type of vehicle will have its own distinctive field of use in which it will prove, on the score of suitability and economy, practically unassailable.

In spite of the fact that it has to provide and maintain its own roadway, and that this accounts for by far the greater part of the total capital expenditure, the average cost of operating electric tramcars in this country indicates that this method of transit is still the cheapest where the traffic to be catered for warrants the outlay. The trolley omnibus, again, has proved a cheaper means of conveyance than the petrol omnibus, in spite of having to bear the additional capital charges of the trolley line and feeders. Both these examples are only instances, out of many, showing that when electric driving can be suitably applied and combined with the supply of electrical energy from a central station, the results as regards convenience, economy, and reliability are incomparably superior to those of the small independent power plant.

The electric battery vehicle is only another instance of the same kind. It also draws its energy from the central station—not continuously, I agree, but it is able to take it at times which are very convenient to the supplier, and under conditions that properly allow of a low price per unit being charged. There is certainly a loss in charging and storage, but in comparison with the electric tramcar and the trolley omnibus, this loss can to some extent be set off against the loss in transmission connected with the two latter systems. I think that these analogies, together with the well-known simplicity of the electric vehicle, its freedom from vibration, and the consequent lessened wear and tear, will go far to explain and make clear to the layman the reason why it proves in actual service to be so economical and reliable.

It is in the displacement of the horse that the real economic future of the electric vehicle lies. For haulage purposes in cities and large towns the days of the horse are numbered. The congested state of our thoroughfares demands his removal, and upon the basis of operating costs, the electric vehicle is the only type of power-driven machine that can take his place. The relief of the traffic congestion in the main streets of our large cities and towns is well known to be an acute and pressing question. There is naturally a limit to the number of vehicles that can be accommodated in any street; and in very many cases that limit has already been reached. What is to be done? A general widening of main thoroughfares is economically out of the question. More efficient use must be made of the present street area. One obvious method of obtaining relief, then, is to bar horse haulage entirely. A pair of horses and a large van take up nearly double the street area required for an average motor vehicle of the same capacity, and for equal carrying capacity the electric vehicle, by reason of the simplicity and compactness of its mechanism, takes up the least space of any.

Considerable further relief of the congestion would follow from the fact that a good commercial motor vehicle can do in the same time more than twice the amount of work of two double-horse teams in city service. If we consider for a moment the enormous delays that are at present taking place in the delivery of merchandise in our cities, and also the cost of these delays, which ultimately resolves itself into a tax upon the consumer, we can easily realise the immense saving that would accrue to the business community by the wholesale adoption of motor transport for city service. But the already extensive adoption of the petrol type of commercial vehicle for this purpose has brought in its train conditions which, I suppose, nobody will deny have not added to the amenities of city life. The noise and smell from that class of vehicle have frequently been the cause of bitter complaint. Both these disagreeable features are, of course, absent from the electric vehicle, and for this reason alone it should assuredly commend itself for universal adoption in large cities and towns.

The position of the electric vehicle can hardly be considered apart from methods of charging its battery. With the batteries at present fitted, the impressed voltage required towards the end of the charge is in the neighbourhood of 110 volts to 120 volts. Since the supply pressures in use are generally above 200 volts, it follows that in most cases the charging must be done through the medium of some pressure-reducing apparatus. If the use of the electric vehicle is to reach the proportions that we so ardently desire, it is essential that the charging operation should be made as simple as possible; in fact, it should be made—as it can be made—practically automatic. It therefore remains for the central station authorities and the manufacturers to see that reliable automatic apparatus is provided. It should be so constructed that when the correct terminal voltage for the whole battery (which is a good approximate indication of the battery's condition) has been reached, the motor-generator is automatically shut down. It is of great importance that vehicles should be able to run into any place where charging facilities are provided, and get connected up with ease. This points to the necessity of standard charging receptacles and plugs.

I propose to conclude these very general remarks by touching upon the work that is necessary in order to bring the uses and advantages of the electric vehicle before the general public. At the outset I would say that in my opinion we cannot look for much assistance at the present time from existing motor traders and garage proprietors. They are in possession of an established business in connection with the petrol vehicle, at which no doubt they are making good profits. They do not want that business interfered with, and they may have grave doubts as to the utility of the electric vehicle. As to its mechanism, its merits, and its economy, they are profoundly ignorant. They will only wake up to its possibilities when they see a created business around them and find a reduction in the sales of the petrol vehicle. In the meantime, then, the pioneer work has to be done, and it behoves the electricity supply authorities, as those who are going to benefit most by the extension of the use of the electric vehicle, to work hand in hand with the manufacturers and to carry on an active propaganda for advertising the electric vehicle.

We have got to educate the public and also those in charge of garages. We must show them that because the vehicle is electric it is by no means complicated; in fact, it is by far the simplest and most sturdily constructed power-propelled vehicle at present on the road. We must advertise all its other good qualities, its ease of driving, its all-round economy, and its reliability. I believe that the story of electric vehicle progress in Great Britain, as it will be told a few years hence, will be such as to constitute a complete rebuke to present-day sceptics. I believe it will be a story of splendid progress, a record of fine achievement.

The Junior Institution of Engineers: Sheffield Branch.—The first meeting of the Sheffield and District Section of the Junior Institution of Engineers was held in Sheffield on March 27th, when Mr. J. R. Williams read a paper on "The Balancing and Torque of Reciprocating Engines." The following officers were elected for the ensuing year: President, Mr. J. Little, M.I.M.E.; chairman, Mr. Thomas Firth; vice-chairman, Mr. F. W. Mellows.

Manchester Association of Engineers.—The annual general meeting of the above association was held on Saturday last, the chair being taken by Dr. Edward Hopkinson, President of the Association. The Secretary submitted the annual report of the Council for the year ending December 31st, 1913, from which it appeared that the number of members on the roll amounted to 646, and that the surplus of receipts over expenditure for the year was £251. 3s. 9d., the net cash balance standing to the credit of the association being £6,547. 5s. 7d. Mr. Edward G. Hiller, the Chief Engineer of the National Boiler and General Insurance Company, Ltd., of Manchester, was elected president for the ensuing year, and Mr. William Fox, the Chief Mechanical Engineer of the Manchester Ship Canal, was appointed a trustee ex the late Sir William H. Bailey. After a few remarks from the President (Dr. Hopkinson) upon the increasing prosperity and progress of the association, an exhaustive paper was read by Mr. J. C. Maxwell Garnett, M.A., Principal of the Manchester School of Technology, on "The Education of Engineers."

INDUSTRIAL AND TRADE NOTES.

Oil-storage Tanks at Capetown.—Operations are proceeding at the Capetown docks for the erection of three large steel tanks for the storage of oil. The tanks will each contain 4,000 tons of oil, and the total capacity of the three will be 2,688,000 gallons of liquid fuel. The oil will be delivered to ships by means of 10in. steel piping laid beneath the quay surface, and will also be available for manufacturing and other purposes.

Observance Tests on Railways.—Two million surprise tests were made during 1913 by the Pennsylvania R.R. in ascertaining the observance of train-safety rules. The average result was 99·9 strict observance. Out of 56,929 tests of signals, 99·4 per cent. showed perfect observance by employés. Of 2,705 caution signals, only 8 cases of disregard were found. Some 16,000 tests were made for flag signal observance by enginemen and only 11 cases of negligence were noted. The 133,000 observations on handling explosives and inflammables showed 152 infractions of rules. Only 18 derelictions were found in 137,175 cases of tests to ascertain whether trains were leaving or arriving ahead of time.

German Steel Production.—According to the annual statistics published by the Verein Deutscher Eisen und Stahl Industrieller there were in operation in Germany in 1913 249 steel making plants, of which 28 were producing basic Bessemer ingots; three, acid-Bessemer ingots; 75, basic open hearth ingots; 14, acid open hearth ingots; 49, basic steel castings; 39, acid steel castings; 26, crucible steel; and 15, electric-furnace steel. In 1912 there were 249 steel making plants in operation. The total production in 1913 was 18,958,819 metric tons, comprising 535,293 tons of acid steel, 18,222,598 tons of basic steel, 99,173 tons of crucible steel, and 101,755 tons of electric steel. In every case the figures show an increase over the production in 1912, the total for which amounted to 17,301,998 metric tons.

Electrical Development in Japan.—According to the local press the last eight years have witnessed a great development in the Japanese electrical industry. During this period the capital invested in electrical supply undertakings and electric railways increased from £2,858,000 in 1903 to £47,163,000 in 1911. During this same period the total electric power for which sanction had been given rose from 44,000 kw. to 344,000 kw., the length of transmission lines increased from 5,981 to 33,584 miles, the length of electric railways grew from 93 miles to 704 miles, whilst the total power of electric motors installed rose from 3,000 kw. to 33,000 kw. This rapid development in all directions caused a great increase in the demand for all kinds of electrical machinery, tools, and materials, and various factories were accordingly set up in Japan. The native works do not, however, make much more than motors, transformers, and switchboards.

Trade Circulars.—We have received from Messrs. S. H. Heywood and Co., Ltd., Reddish, near Stockport, an exhaustive illustrated catalogue showing various installations of their electric transporter cranes, a type of hoisting apparatus that is now becoming extensively applied in engineering and other works, where rapid and quick transport of materials is required without interfering with ground space. The illustrations show how advantageously this method may be applied, and we commend it to the attention of all who are interested in the lay-out of new or re-organisation of old plant. The Castolin Company, Clock House, Arundel Street, Strand, W.C., send us a copy of a new handbook, giving a number of typical illustrations showing the application of their autochemical welding process. These clearly indicate the wide range of repairs, breakdowns, and defects which may be remedied by their system. Thos. Andrews & Co., Ltd., Royds Works, Sheffield, send us price lists of their drills, files, and cold drawn steel bars.

A National Bureau of Labour Safety in the United States.—The United States Government has passed a Bill creating a Bureau of Labour Safety in the Department of Labour. The Bill provides for a commissioner of labour safety and other employés, and outlines the duties of the bureau as follows: "To make general and special investigation and examination of labour safety plans and devices of all kinds, and the need therefor, generally and specifically, and also the study of all phases of the subject of vocational diseases, and to make public the results of such investigation, examination, and study from time to time; also, to gather, compile, publish, and supply useful information concerning the use of labour safety plans and devices and vocational diseases in the industries of the United States and elsewhere." The Bill also provides for the erection of a museum of sufficient size and capacity, in which will be exhibited approved devices for the safe-guarding of machinery, the protection of employés from injury, the lessening of dangerous conditions which may exist in any industrial enterprise, &c.

Prospects of a South African Mineral Oil Industry.—A report on the petroleum prospects in the Union of South Africa has been prepared by Mr. E. H. Cunningham Craig, B.A., F.G.S., who has been carrying out investigations on behalf of the South African Government. This states that the results of the investigations show that there is little likelihood of any extensive oil fields being found anywhere in the Union. As regards natural gas, it is stated that there are areas in the coal measures in the Transvaal and Natal where it can be struck in fair quantity. Supplies of gas under sufficient pressure to supply distant towns are improbable, but the gas may possibly be used locally at a profit. None of the shales examined, with the exception of that at Kikvorsch fontein, are comparable with the best Scotch shales, but the laboratory tests prove that very fair quantities of shale oil can be produced. The seams are unfortunately thin as a rule, which will greatly increase the cost of working. Against this it must be remembered that the demand for oils in South Africa is large, that present prices are very high, and that freight charges are high also. Thus a shale too thin to be worked at a profit in many countries might prove quite profitable in South Africa. All the evidence to hand at present leads to the belief that an oil-shale industry has good prospects of proving successful, and no effort should be spared to ensure that a fair test is made of its possibilities.

The Extension of Trade Boards.—The text of a Bill to provide for minimum rates of wages and maximum hours of labour, and to regulate the conditions of labour, presented by Mr. Barnes, M.P., and supported by Mr. Brace, Mr. Gill, Mr. Snowden, and George Roberts, was issued on March 26th. The measure provides that the Board of Trade is to establish one or more Trade Boards in any trade in which, in the opinion of the Board of Trade, the usual wages of an adult worker of either sex do not exceed 25s. a week, and in any other trade in which the establishment of a Trade Board is desired by a majority of the persons engaged, whether as employers or employés. Such Trade Boards are to fix minimum wages, and may also fix general minimum wages for piece work, and such rates may be fixed so as to apply universally to the trade or to any special process or to any special class of workers or to any special area in that trade. The Boards are also to fix the minimum hours of labour, also meal times and holidays. A penalty not exceeding £20 and a fine of £5 for each day the offence is continued after conviction is to be imposed on any employer who does not pay wages according to the minimum rate made obligatory. Boards are to represent employers and employés alike, and the chairman shall be such member as the Board of Trade shall appoint, the Board also appointing the secretary. A Trade Board may establish district trade committees consisting partly of its own members and partly of other persons representing employers or workers engaged in the trade and acting for such area as the Trade Board may determine.

Canadian Mineral Production.—A preliminary report on mineral production in Canada in 1913, prepared by John McLeish, chief of the division of mineral resources and statistics, Department of Mines, Ottawa, shows a total value of production in the year of $144,031,047. The total value of the production in 1912 was $135,048,296. Not only has the total output increased from a little over $10,000,000 in 1886 to its present output, but the average production per capita has increased from $2.23 per capita to $18.57, or eight times the rate shown by the first record.

	1912.		1913.	
	Quantity.	Value.	Quantity.	Value.
		Dollars.		Dollars.
Copper ....Lbs	77,832,127	12,718,548	76,975,832	11,753,440
Gold ....Ozs.	611,885	12,648,794	784,525	16,216,131
*Pig iron ....Net tons	42,355	450,886	73,508	996,429
Lead ....Lbs.	35,763,476	1,597,554	37,662,703	1,754,705
Nickel ....Lbs.	44,841,542	13,452,463	49,676,772	14,903,032
Silver ....Ozs.	31,955,560	19,440,165	31,750,618	18,984,012
Asbestos and asbestic Tons	136,301	3,137,279	161,086	3,849,925
Coal .... Tons	14,512,829	36,019,044	15,115,089	36,250,311
Petroleum .... Brls.	243,336	345,050	228,080	406,439

*From Canadian ore.

The production of the more important metals and minerals is shown in the above tabulated statement, in which the figures are given for the two years 1912 and 1913 in comparative form. The Dominion of Canada does not include Newfoundland. The production of pig iron in Canada is largely from ore imported from Newfoundland and the United States, and such pig iron is excluded from these statistics.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1913.

Rotary engines. Clark. 3325.
Internal combustion engines. Constantinesco. 3407.
Journal bearings. Parsons. 5619.
Pumping apparatus for the manufacture of tubes, wires, &c., of indefinite length from metals or alloys. Debauge. 5639.
Welding burner with oxygen injector. Worringen & Eikar Werkzeuge Ges. 5723.
Oxy acetylene blow pipes. Roubinowitch. 5724.
Water-tube boilers. Van Oosterwyck. 5812.
Unloading conveyers for ships. Overton. 6038.
Boiler-tube cleaners. Lamb. 6065.
Variable-speed hydraulic multiplying and reducing apparatus. Soc. Anon. des Ateliers et Chantiers de la Loire, & Tourreil. 6076.
Mounting and driving of live axles of motor road vehicles. Wolseley Tool and Motor Car Company Remington and Rowledge. 6117.
Carburetters for internal-combustion engines. Welch 6146.
Preparation of finely divided metallic copper. Craig, and Peter Spence & Sons, Ltd. 6161.
Gas producers. Carretero. 6262.
Spanners. Oesterreich. 6368.
Liquid fuel spraying devices. Babcock & Wilcox, Ltd. 6492.
Apparatus for regulating compound steam engines. Schou. 6569.
Means for ascertaining the hardness of metals. Rudge Whitworth, Ltd., and Heathcote. 6622.
Motor vehicles. Alexander. 7256.
Variable-speed friction gear. Bell. 7358.
Pneumatic conveying apparatus. Yates and Matthews and Yates, Ltd. 8311.
Carburetters for internal combustion engines. Wilkinson. 8317.
Rotary explosion engines. Bjarnov. 8468.
Pressure intensifying apparatus for hydraulic presses and press tools. Hele Shaw, Beacham, & Rickwood. 8726
Steam turbines. Rockman. 8862.
Induction pipes of internal-combustion engines. Stubings, and W. H. Dorman & Co. 9693.
Centrifugal pumping apparatus. Adams. 9721.
Apparatus for storing and delivering inflammable liquids. Hoffmann. 9883.
Method of and apparatus for holding percussion tools. Haas. 9923.
Internal-combustion engines. Slavescu. 10916.
Steam injectors. Gresham & Gresham. 11269.
Multiple spindle drilling machines. Ash. 11331.
Pressure producing means for use in measuring, controlling, and indicating temperatures. Steenbjerg. 11393.
Explosion motors. Ruva. 11588.
Device for use in charging and discharging retorts and muffles. Von Zelewski. 12120.
Carburetters for internal-combustion engines. Hawxhurst and Nicolai. 12204.
Steam generators and superheaters. Gianotti & Gianotti. 12657.
Internal combustion engines. Mellersh-Jackson. 12820.
Annealing of wire. Woods. 12872.
Rotary engines and pumps. Brennan. 12884.
Worm gearing. Fleury & Morin. 13189.
Carburetters for internal-combustion engines. Miller & Adamson. 13454.
Gas engines. Daniel. 13456.
Process for removing sulphuretted hydrogen from gases. Burkheiser. 13724.
Means for converting rotary movement into reciprocating movement. Dollman. 13794.
Automatic train stop devices. Hudson. 14336.
Methods of and apparatus for sintering metal. Walling. 14795.
Bearings for shafts. Delmez. 15627.
Controlling mechanism for valves. Bloch. 15820.
Railway signalling apparatus. Soc. d'Electricité Nilmelior, and Colas. 16641.
Valves. Hart. 16647.
Recovery of nickel from its ores. Sulman, Picard, & Roberts. 17131.
Carburetters for internal-combustion engines. Johnson. 17767.
Spark-plug socket for oil and gas engines. Male. 18728.
Railway rail joints. Surtig, Briar, & Meno. 19101.
Wire drawing apparatus. Frese. 19276.
Carburetter for starting internal-combustion engines. Laughton. 20080.
Explosion turbines. Bauch. 20513.
Method of and apparatus for pumping or raising liquids. Melliss. 22012.
Safety suspension mechanism for mining cages. Horsley. 22282.
Governor mechanism for compressor engines. Teague. 23807.
Liquid fuel supply to furnaces. Soc. Anon des Etablissements Delaunay Belleville. 24059.
Valves for internal combustion engines. Ayers. 24352.
Starting internal combustion engines. Heins. 24457.
Wave motors. Gifthorn. 25793.
Furnace provided with regenerative chambers. Poetter, and Poetter Ges. 26411.
Lock nuts. Erwin. 26629.
Carburetters for use with internal combustion engines. Claudel. 26927.
Operation of the throttles or starting valves of locomotives. Hudson. 27181.
Alloy for white metal goods. Wilkins. 27406.
Superheaters for water tube boilers. Yarrow. 27558.
Apparatus for removing ashes from stoke holes, also applicable as a bilge pump. Soc. Anon. Westinghouse. 28290.
Moulding flasks. Dupler. 28404.

1914.

Carburetters for internal combustion engines. Cox. 1488.

ELECTRICAL, 1912.

Electrical resistances. Hay & Sullivan. 22375.

1913.

Electric recording devices. British Thomson Houston Company. 5731.
Dynamos. Newton, and Newton Bros. 5926.
Methods of starting the arcs of electric furnaces. Scott. 6136.
Timing device for use with electric switches. Bendixen and Gondrup. 6169.
Electric train signalling and controlling systems. Allard. 6186.
Selective system of telephony. Hastings. 9986.
Telephone systems. Siemens and Halske Akt. Ges. 12060.
Apparatus for use in wireless telephony. Ditcham, and Grindell-Matthews Wireless Telephone Syndicate, Ltd. 12076.
Apparatus for heating liquid electrically. British Electric Heater Company, and Kratt. 12129.
Wireless telephony and telegraphy. Ditcham, and Grindell-Matthews Wireless Telephone Syndicate, Ltd. 12157.
Telephone exchange switching systems. Telephon Apparat Fabrik E. Zwietusch & Co. 14229.
Magnetic separators. Fried. Krupp Akt.-Ges. Grusonwerk. 14427.
Arrangements for controlling the feed of recording instruments. Siemens Bros. & Co. 14951.

1914.

Electric switches. Hart. 340.
Sparking plugs. Freiberg & Petzsche. 357.
Connections and fittings for electric conduits. Birch. 1729.

METAL QUOTATIONS.

TUESDAY, MARCH 31ST.

Aluminium ingot	86/- per cwt.
,, wire, according to sizes, &c. ......from	112/- ,,
,, sheets ,, ,, ... ,,	112/- ,,
Antimony	£27/10/- to £29/10/- per ton.
Brass, rolled	7¼d. per lb.
,, tubes (brazed)	9⅝d. ,,
,, ,, (solid drawn)	7⅞d. ,,
,, ,, wire	7⅜d. ,,
Copper, Standard	£64/17/6 per ton.
Iron, Cleveland	50/9 ,,
,, Scotch	56/9 ,,
Lead, English	£18/10/- ,,
,, Foreign (soft)	£18/7/6 ,,
Mica (in original cases), small	6d. to 3/- per lb.
,, ,, ,, medium	3/6 to 6/- ,,
,, ,, ,, large	7/6 to 11/- ,,
Quicksilver	£7/-/- per bottle.
Silver	26¾d. per oz.
Spelter	£21/7/6 per ton.
Tin, block	£173/10/- ,,
Tin plates, I.C.	13/- per box.
Zinc sheets (Silesian)	£24/15/- per ton.
,, (Stettin; Vieille Montagne)	£25/2/6 ,,

The Mechanical Engineer.
An Illustrated Weekly Journal
Vol. 33, No. 846

Edited by
WILLIAM H. FOWLER,
Wh. Sc., M.Inst.C.E.

Telegrams: "Scientific," Manchester.
Telephone No. 6055 City.

SUBSCRIPTION RATES.

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Marine Engineering and Shipbuilding.

While some of the figures given in the admirable review of our progress in marine engineering and shipbuilding portrayed in the presidential address at the Institution of Naval Architects are gratifying to national pride, others give rise to serious reflection, while others again indicate the magnitude and difficulty of the problems that lie immediately ahead notwithstanding the big steps that have been made during recent years. Last year's output of shipbuilding was a record. Merchant ships totalled no less than 1,932,000 tons and warships over 271,000 tons, giving a grand total of 2,203,000 tons for British yards out of a total output for the whole world of a little over 4,000,000 tons. While it is pleasing to reflect that no less than 58 per cent. of the output for 1913 fell to British industry, the fact must not be overlooked that in 1911 the percentage was 68, or, taking another basis for comparison, "while our output has increased during two years by 128,000 tons that of foreign shipbuilding has increased in the aggregate by 554,000 tons." Our supremacy is undoubted, but it would be foolish to ignore the efforts of our competitors or the strides they have made. Competition in engineering matters is becoming increasingly one between brains, and enhances the importance which all thoughtful observers attach to the questions of higher education and research work if our supremacy is to be maintained.

One of the most salient features in connection with mercantile ship construction is the continued growth in the size of individual units. Taking ships of 6,000 tons and over, it appears that while the yearly average during the five years 1908-12 was 41, no less than 84 such ships were launched in 1913; and a similar comparison with ships of 10,000 tons and upwards was even more striking, the average for the five years being 11 as compared with 21 for the year just closed while the largest of these—namely, the "Aquitania"—has

a tonnage of no less than 47,000 tons. Further growth on the part of these monster Atlantic liners is, as we pointed out a little while ago, giving rise to some very serious difficulties in connection with harbour and dock accommodation, and threatens to prevent further growth except in special cases apart from the special problems associated with the construction and propulsion of the vessels themselves. There has, however, been no disposition on the part of either owners or builders to shirk them, and if a check is experienced as regards development in size, it will be from other and outside considerations. The solution of the problems of propulsion have undoubtedly been largely aided by the development of the steam turbine which, where large units of power are concerned, has established itself as a standard type of prime mover, while its successful conjunction with gearing promises to extend its range of economical application to nearly all classes of ships. To what extent the turbine steamer will be supplanted by the motor-driven ship is still an open question. The progress made, however, has been noteworthy, and the fact should also be recognised that continental engineers have mainly contributed to it. But apart from the mechanical difficulties of Diesel engines, which in large sizes are especially serious, the questions of supply and cost of oil introduce economic questions that are at present not easy to answer, and on which shipbuilders will require further enlightenment before this type of prime mover is adopted on a large scale.

The Trend of Invention.

A review of the figures presented by the Comptroller-General of Patents in his annual report, just published, forcibly illustrates the truth of the adage that "Necessity is the mother of invention." Ingenious ideas and scientific discoveries are not, as many people imagine, so much the product of happy inspiration as the outcome of hard, patient thinking and experiment suggested by some trouble or difficulty arising out of human desires or needs, pointed, it may be, by a wish to reduce risk of accident or by a desire to increase profit or diminish cost, or in some other way to balance the economic forces that always beset more or less industrial enterprise. The terrible accidents that have arisen from the failure of signalling arrangements on railways during the last year or two have stimulated interest in devices for making them automatic and independent of the human element. Accidents in mines and recent legislation arising out of them have in a similar way brought inventive talent to bear on methods of signalling in mines. The increasing development of the motor-vehicle industry has opened quite a number of avenues for the exercise of mechanical ingenuity, and is reflected in the fact that the number of applications for patents in this direction has increased during the past year by about 25 per cent. Aeronautics, too, still offer many problems and difficulties for solution, particularly in connection with the working of internal-combustion engines combining the antagonistic qualities of great power and lightness. Out of the huge growth of this type of motor have sprung other difficulties. The abnormal demands for motor spirit have led to enhanced prices, and the search for other sources of supply have set the chemists a number of special problems, and led to the taking out of quite a host of patents concerned with improved methods of abstracting them from heavy hydrocarbon oils, or distillation of other carbonaceous substances. Human amusement offers no less tempting prizes than industrial efficiency to those who can cater for its needs. The popularity of the cinematograph and the efforts to improve its adaptability to the simultaneous reproduction of sound and colour have led to quite a multitude of new inventions relating to the solution of the problems thus presented. A reference to the income and expenditure of the Patent Office shows that notwithstanding the additional assistance which the Patent Office has afforded inventors during recent years, it is still a very profitable Government department, for during the past year, while the expenditure of the Office amounted to £194,423, the receipts were no less than £346,324, showing a surplus of £151,901, as compared with a surplus of £131,627 in 1912.

IRON AND STEEL INSTITUTE.

The annual meeting of this Institute will be held in the new House of the Institution of Civil Engineers, Great George Street, Westminster, on Thursday and Friday, May 7th and 8th, commencing each day at 10-30 a.m. On the Thursday the Council will present their report for the year 1913, and the hon. treasurer the statement of accounts for 1913. The retiring President (Mr. Arthur Cooper) will induct into the chair the President-elect (Mr. Adolphe Greiner). The Bessemer Gold Medal for 1914 will be presented to Mr. Edward Riley, F.I.C. The President will deliver his inaugural address, which will be followed by the reading and discussion of papers. The annual dinner of the Institute will take place at the Connaught Rooms, Great Queen Street, W.C., at 7 p.m. On the Friday the Andrew Carnegie Gold Medal (for 1913) will be presented to Mr. Thomas Swinden, D.Met., and the award of research scholarships for the current year will be announced. The following is the list of papers that are expected to be submitted for reading and discussion: (1) J. O. Arnold, D.Met., F.R.S., and G. R. Bolsover: "The Forms in which Sulphides may Exist in Steel Ingots." (2) C. Benedicks, Ph.D.: "Experiments on Allotropy of Iron (behaviour of ferro-magnetic mixtures; dilatation of pure iron)." (3) A. Bose: "Recent Developments of the Iron and Steel Industry in India." (4) C. Chappell: "The Recrystallisation of Deformed Iron." (5) C. A. Edwards, D.Sc., and H. C. H. Carpenter, Ph.D.: "The Hardening of Metals, with special reference to Iron and its Alloys." (6) J. N. Friend, D.Sc., and C. W. Marshall: "Influence of Molybdenum upon the Corrodibility of Steel." (7) H. C. Greenwood, D.Sc.: "Note on a curious case of Decarburisation during the Hardening of Steel Dies." (8) Sir Robert A. Hadfield, F.R.S., and B. Hopkinson, F.R.S.: "The Magnetic and Mechanical Properties of Manganese Steels." (9) H. L. Heathcote, B.Sc.: "Some Improvements in Case-hardening Practice." (10) S. A. Houghton: "Failures of Heavy Boiler Shell Plates." (11) E. Humbert and A. Hethey, B.Sc.: "Production of Steel Direct from the Ore." (12) A. McCance, B.Sc.: "Theory of Hardening." (13) M. Misson: "The Colorimetric Estimation of Sulphur in Pig Iron and Steels by means of Paper Impregnated with a Solution of Arsenious Anhydride in Hydrochloric Acid." (14) F. Müller: "The Development of Dry Cleaning in Blastfurnace Gas Purification." (15) W. Rosenhain, D.Sc., F.R.S., and J. L. Haughton, M.Sc.: "A New Reagent for Etching Mild Steel." (16) F. Schuster, D.Ing.: "Results of Talbot Process at Witkowitz." By the kind invitation of the Comité des Forges, the autumn meeting will be held in Paris on September 18th to 23rd, 1914.

The Smoke Abatement Bill.—In the House of Lords recently Lord Newton moved the second reading of his Smoke Abatement Bill. Lord Allendale, on behalf of the Local Government Board, said they were in entire sympathy with the objects of the Bill, but the President proposed to appoint a strong Departmental Committee to enquire into the question and to make a report before asking Parliament definitely to commit itself to an amendment of the law. On this assurance Lord Newton asked leave to withdraw his motion, and the Bill was therefore withdrawn.

REAVELL'S THREE-STAGE AIR COMPRESSOR.

A DESIGN of three-stage air compressor, the invention of Messrs. Reavell & Co., Ltd., Ranelagh Works, Ipswich, is shown in the accompanying illustrations, Fig. 1 being a vertical section, Fig. 2 a side view of the driving mechanism at right angles to Fig. 1 and a section through the cylinders, Fig. 3 a plan of the compressor, Fig. 4 a section along the crosshead, Fig. 5 a plan of the intermediate compression

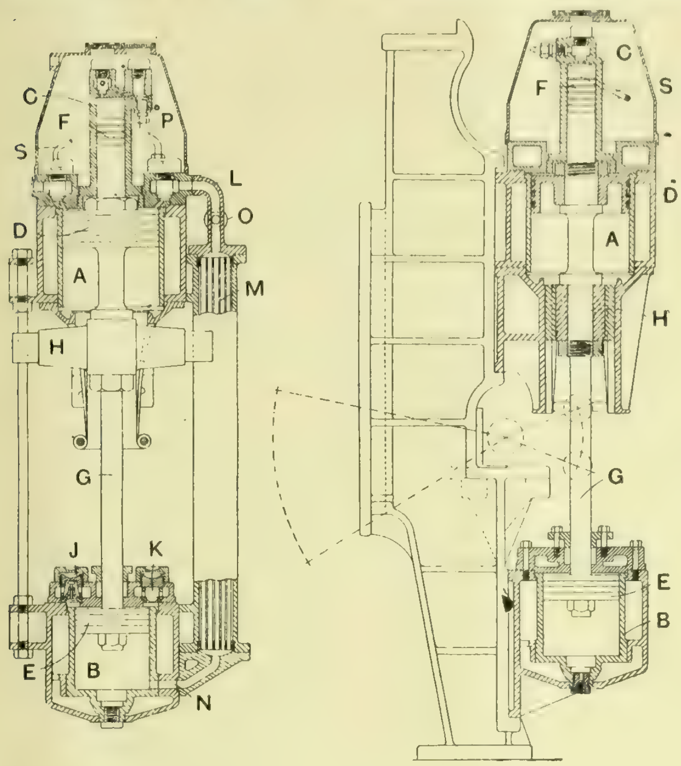


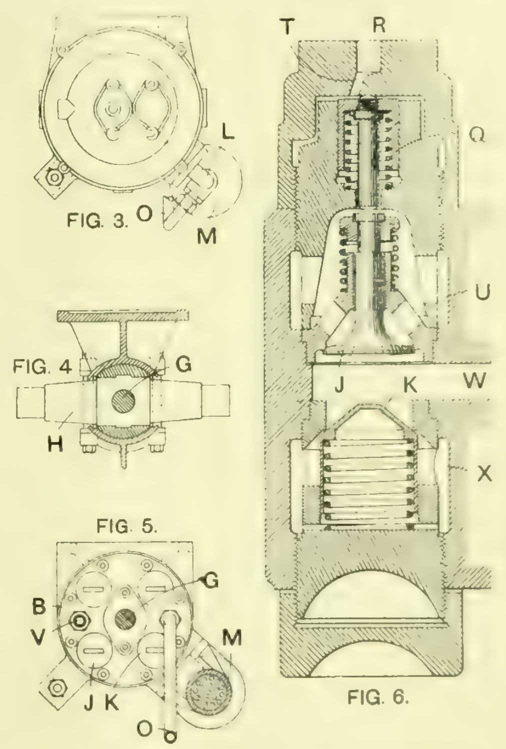
FIG. 1. FIG. 2.

REAVELL'S THREE-STAGE AIR COMPRESSOR.

cylinder, and Fig. 6 a vertical section on a larger scale of a pair of valves of a double-acting intermediate cylinder provided with automatic regulation for the low-pressure side. A is the low-pressure cylinder and C the high-pressure cylinder placed axially above the low-pressure cylinder. Their pistons D and F are rigidly connected and single acting. The intermediate cylinder B is mounted on the opposite side of the driving mechanism and co-axial with the other cylinders. The low-pressure piston D is connected with the intermediate piston E by a piston rod G, on which is mounted a crosshead H set in motion by a pair of oscillating levers through the intermediary of links. The air, which has been compressed in the cylinder A provided with an ordinary inlet valve and outlet valve, passes through the outlet L into the pipes M of an intercooler and then through the admission port N directly into the lower end of cylinder B without the intervention of a valve. The upper end of the intercooler communicates with the pipe P leading to the inlet valve of the high-pressure cylinder, and the air which has been compressed in the latter escapes through an outlet controlled by a valve into the discharge pipe S leading to a receiver. At the end of the downward stroke of the intermediate piston E a portion of the air compressed in the lower part of the cylinder B and then cooled in the intercooler enters the cylinder C. During the subsequent return or upward stroke of the piston E the air remaining in the intercooler expands against the piston, thereby returning to it a portion of the work done during the down stroke.

The upper end of the intermediate cylinder B is closed by a cover provided with a suction valve box J and a discharge valve box K, from which a branch O leads to the air conduit extending from the pipe L, through the intercooler to the port N. The upper side of the piston E and cylinder B may be rendered single acting by keeping the suction valves J open during the forward and backward strokes of the piston E, so that the pressure above the piston cannot become substantially higher than that of the atmosphere, and the discharge valves K will remain closed, or the suction valves may be held closed, thus allowing the air above the piston which is not delivered through delivery valves, to be alternately expanded and compressed. The suction pipe V leading to the suction valves of the auxiliary cylinder may be provided with an ordinary valve, which can be operated by hand, if it is desired to set the auxiliary cylinder into or out of action or to adjust the volume of auxiliary air admitted independently of the receiver pressure. If the valves of the upper end of the cylinder B act in the usual manner of pump valves, the down-stroke of the piston E draws air into the cylinder through the suction valves J, and the subsequent up stroke compresses the air, which then escapes through the discharge valves K and branch pipe O into the line of pipes connecting the cylinders A and B. The compressed air discharged from the upper end of the cylinder B is therefore added to that which flows from the cylinder A to the cylinder B, and the upper part of cylinder B may thus be made to act as an additional low pressure cylinder.

This auxiliary action of the cylinder B may be made dependent on the pressure of the air in the receiver fed by the discharge pipe S of the high-pressure cylinder C. The pressure in the receiver will vary according to the volume of air abstracted from the same for various purposes. If the volume is greater than that supplied during the same time by the pipe S the pressure will fall, in which case it is desirable to increase the supply of air by increasing the output of the low-pressure stage of the compressor. This may be done automatically by the device shown in Fig. 6, where J is the suction valve, whose spindle is provided at the top with a collar resting on a spring adapted to hold the valve in its closing position. Into the valve box is screwed a casing, which contains at the top a vertically movable box Q supported by a spring and containing a spindle which terminates a short distance above the spindle of the valve J. The upper part of the casing extends into a cap, provided at the top with a socket R for a pipe communicating with the receiver. A duct T leads from the socket to the interior of the cap. The casing has lateral openings communicating with the port U open to the atmosphere, while the port W communicates with the upper end of the cylinder B. In the position shown by the drawing the valve J is free to open



REAVELL'S THREE-STAGE AIR COMPRESSOR.

and close. If the pressure in the receiver exceeds the desired maximum, the spring box Q is forced down, and its spindle forces down the valve J, so as to keep it open until the pressure in the receiver has dropped sufficiently for allowing the valve to close and act in the normal manner; K is the delivery valve communicating with the interior of the cylinder B through the port W and with the pipe O through the port X.

MUNTZ METAL.*

By J. E. Stead, D.Sc., D.Met., F.R.S., and H. G. A. Stedman.

Although a great amount of general work has been done on brasses, there is still necessity for more. As the structure of Muntz metal varies according to the heat treatment and rate of cooling to which it has been subjected, we decided on making trials to correlate the composition, microstructure, heat treatment, and physical properties of metal containing about 60 per cent. copper and 40 per cent. zinc. Our scheme was to heat duplicate series of the metal of determined composition for 48 hours at temperatures between 470° C. and 860° C., allowing one set of bars to cool in the air, quench the other set in cold water, and then to examine them afterwards. Mr. F. Tomlinson, of Messrs. The Broughton Copper Company, Ltd., Manchester, most kindly supplied the bars of brass in the form of cold-drawn round bars, ½in. diam. The apparatus for heating the metal was supplied by the Cambridge Scientific Instrument Company, Cambridge, and consisted of a resistance tube electric furnace and a Whipple pyrometer.

Table I.

No.	Maximum, Degrees C.	Minimum, Degrees C.	Mean, Degrees C.	Range, Degrees C.
1	495	462	475	33
2	580	556	565	24
3	685	665	675	20
4	742	715	720	27
5	757	740	749	17
6	783	765	773	18
7	835	785	812	50
8	845	820	833	25
9	880	846	860	34

The bars in duplicate were placed in the centre of the furnace and the pyrometer tube placed over them. When in position the open ends of the furnace were closed by loose asbestos. Soon after commencing the experiments it was found impossible to maintain a constant degree of heat owing to changes in the room temperature. Consequently there was considerable variation during the 48 hours' heating in the furnace, amounting to between 17° and 50° C. The structure, however, varied proportionately to the mean temperature, and, our object being to correlate microstructure and mechanical properties, the bars, after heating over ranges instead of at fixed temperatures, answered the purpose. Two bars were heated at the same time in each trial; one was quenched as soon as removed from the furnace, and the other was allowed to cool in the air. The bars most highly heated cooled down to below 400° C. in ten minutes. Table I. gives a record of the temperature.

Table II.

Mark.	Heat Treatment. Temperature.	Duration of Heating.	Quenched in Water. Yield Stress. Tons per sq. in.	Max. Stress. Tons per sq. in.	Elongation in 1in. Per cent.	Reduction of Area. Per cent.	Cooled in Air. Yield Stress. Tons per sq. in.	Max. Stress. Tons per sq. in.	Elongation in 1in. Per cent.	Reduction of Area. Per cent.
Normal bar of A & B	—	—	—	—	—		15·24	26·18	44	54
A	270	984 hours		—		—	13·76	25·85	54	63
B	430	3 months			—	—	11·52	22·9	56	63·4
Hard drawn	—	—	—	—		—	36·79	39·10	19	54
1	475	48 hours	15·79	26·04	45	66·2	15·07	25·6	50	65·6
2	565	,,	15·15	25·91	41	58·8	13·56	25·11	51	63·1
3	675	,,	14·64	28·67	38	43·8	13·41	26·64	47	58·8
4	720	,,	15·89	27·40	26	37·8	12·27	24·48	40	48·6
5	749	,,	19·67	28·73	20	32·6	14·42	26·38	42	43·8
6	773	,,	20·47	23·26	10	26·6	13·62	25·00	38	43·8
7	812	,,	19·33	29·53	25	26·0	13·08	25·50	48	53·9
8	833	,,	19·62	29·38	26	37·8	12·82	25·55	45	48·6
9	860	,,	18·45	27·22	30	32·1	14·93	24·50	48	58·2

The bars for A and B were different from those of Nos. 1 to 9.

* Abstract of paper read before the Institute of Metals, March 18th, 1914.

As will be shown in the section on microstructure, the β constituent of the bar heated to about 475° C. was apparently in less proportion than was present in the 1—9 series. It was decided to heat other bars at a much lower temperature for a longer time, to determine whether it was possible to effect the complete absorption of the β constituent. Having found a heated flue at the Middlesbrough Gas Works, where the temperature varied between 430° C. and 500° C., an iron pipe closed at one end was inserted in the flue; the bars of brass were placed in it, and were allowed to remain there for three months. Strips of zinc were also introduced, and when the specimens were removed it was found that the bar nearest the outer wall of the flue had not been heated to above 430° C., for only the inner end of the zinc strip had melted. In order to determine the effect of still lower temperatures another bar was put into a superheater at one of the Cleveland & Durham Power Company's stations operating at 270° C., and kept there for 984 hours.

The bars were tested by the Sheffield Testing Works, Ltd., Blonk Street, Sheffield, with results shown in Table II. All the specimens were also tested by the Brinell method, using a 10-millimetre ball and a pressure of 500 kg. By dividing the average tenacity by the average hardness numbers a ratio factor of 0·365 for air-cooled brass was obtained, which is very useful, for by multiplying the hardness numbers by this factor the approximate breaking load is obtained. The actual and calculated tenacities, together with the Brinell number, are given in Table III.

Table III.

Description.	Quenched. 1	2	3	Air-Cooled. 1	2	3
A as received ..	—	—	—	26·18	—	—
1 to 9 as received	—	—	—	39·10	—	—
A	—	—	—	25·85	—	—
B	—	—	—	22·90	—	—
1............	26·04	74	26·6	25·60	70	25·5
2............	25·91	73	27·0	25·11	65	23·7
3............	28·67	83	30·3	26·64	67	24·4
4............	27·40	89	33·5	24·48	67	24·4
5............	28·73	93	33·9	26·38	70	25·5
6............	23·20	100	36·5	25·00	70	25·5
7............	29·53	100	36·5	25·50	70	25·5
8............	29·38	100	36·5	25·55	70	25·5
9............	27·22	93	33·9	24·50	70	25·5

Column 1 gives the determined tenacity in tons per square inch, column 2 the determined Brinell hardness number, and column 3 the tenacity calculated from the hardness number and the factor already mentioned, namely, 0·365. It will be observed that while the hardness of the quenched specimens rises with the temperature of quenching, the calculated tenacity is too high.

The surfaces of the normal cold-drawn piece of brass and Nos. 1 to 3 were smooth. No. 4 was crinkled on the surface. No. 5 was very uneven, and, owing to the peculiar orientation of the crystals, the test-piece had during extension become elliptical in section—6·5 mm. through the longer axis and 5·4 mm. through the short axis. The length of some of the crystals could be traced on the surface, and varied between half and one inch. No. 6 test-piece, quenched in water, owing to the small extension, was smooth on the surface, but the fracture consisted of several terminations of very large crystals which had evidently not been strongly held together, or which had envelopes surrounding them of a weaker substance than their mass. The test-piece of No. 6, cooled in air,

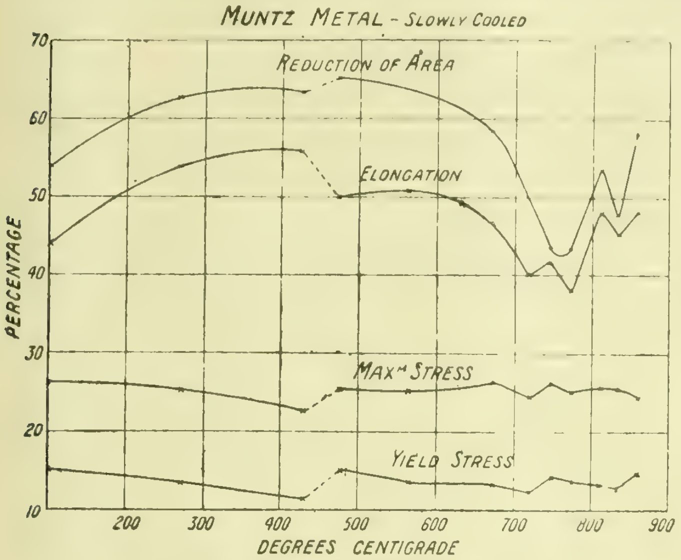


Fig. 1.—Results of Mechanical Testing.

had a crinkled surface, due to the presence of large crystals which flowed unequally during the extension in the testing machine. Nos. 7 and 8 were less crinkled on their surfaces than Nos. 4 and 5, and Nos. 8 and 9 were oval in section—6·7 mm. by 5·7 mm. and 6·5 mm. by 5·7 mm. respectively. With the exception of No. 6 all the fractures were fibrous.

"A." The bar heated for three months at about 430° C. broke with a fibrous fracture, and the surface was smooth.

"B." The bar subjected to the influence of superheated steam also yielded a fibrous fracture.

The result of heating upon the physical properties of the metal is most marked. In general terms the effect of heating followed by quenching, as compared with heating followed by cooling in air, is to raise the tenacity and to reduce the elongation and contraction of area at the point of fracture. On comparing the results obtained on the two bars of No. 1, heated to just above the critical point, it will be noticed that there is practically no difference in the tensile strength, the tenacity of the quenched bar being only 0·45 tons greater, the elongation 5 per cent. less, and the reduction of area at the point of fracture is 0·6 per cent. more than the respective results obtained on testing the air-cooled material. The mechanical properties of the highly heated, air-cooled bars are surprisingly good, and not what was expected.

The best results, so far as ductility is concerned, are those obtained in the case of the bar heated for three months at 430° C. The lowest tenacity is found in the bar heated to 720° C., while that heated to 773° C has the lowest ductility. The most astonishing results, however, are those produced on heating to 860° C., which show only 1·1 ton less tenacity and 2 per cent. less elongation than the bars heated to 475° C. Generally speaking, the ductility of the air-cooled bars decreases with rise of temperature until 773° C. is reached, and then increases with higher heating—a remark which is equally applicable to the bars quenched in water, for the elongation decreases from 45 per cent. in the bar heated and quenched from 475° C. to 10 per cent. in that heated and quenched from 773° C., and rises with higher heating to 30 per cent. in the bars heated to and quenched at 860° C. In the quenched bars, however, the tenacities compared with the duplicate air-cooled bars are, with the exception of No. 6, greater, as is shown in Table IV:—

Table IV.

	Difference of Tenacity between the Quenched and Air-cooled Respective Bars.	
	Plus tons.	Minus tons.
Bars heated to 475° C.	0·45	—
,, 565° C.	0·80	—
,, 675° C.	0·80	—
,, 720° C.	2·92	—
,, 749° C.	2·35	—
,, 773° C.	—	1·71
,, 812° C.	4·03	—
,, 833° C.	3·73	—
,, 860° C.	2·80	—

It is obvious from these results that in the neighbourhood of 773° C. there is a critical or brittle point for this particular brass. Some authorities maintain that 750° to 780° C. is a dangerous zone. Brass heated in that zone has been described as "burnt"—a term, however, obviously inappropriate, for, on higher heating, the material again becomes ductile.

Microstructure of the Alloys. All the specimens previously referred to after polishing were etched with a dilute solution of ferric and hydric chloride. The β constituent was fully developed in about ten seconds. After etching, the surfaces were dried with a clean linen rag. Speaking broadly, as the temperature rises above 470° C. the β constituent increases in accordance with the equilibrium diagram of Shepherd, and when the temperature of heating is a little above 773° or 812° C. the metal specimens consist wholly of the β constituent, which is retained as such—after quenching.

"A" *Alloy.*—In the brass designated "A" the β constituent gradually diminishes during heating to about 430° C. until most of it disappears, and it seems to be probable that if the heating had been prolonged for six months instead of for three, all the β constituent would have been absorbed, or, in other words, the alloy would have become entirely α. The result apparently indicates that the curve b2-b3 in Shepherd's diagram should make an abrupt turn to the right after pass-

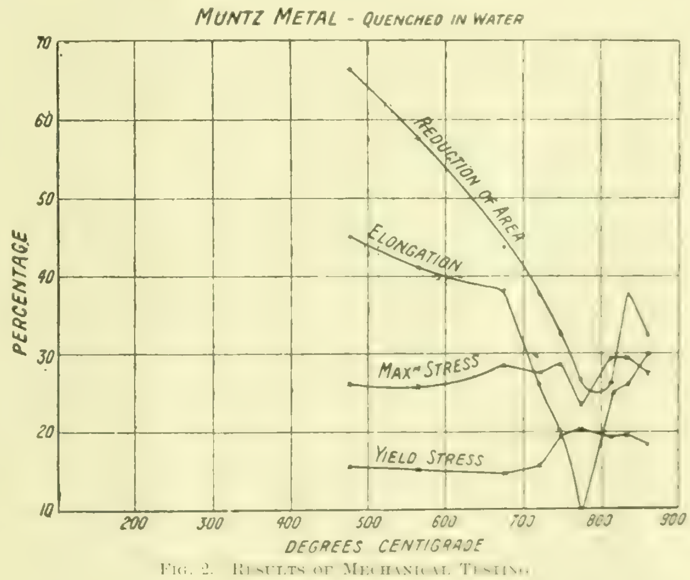


Fig. 2.—Results of Mechanical Testing.

ing about 500° C. The gradually diminishing size of the β segregations does not suggest that the β constituent changes to the γ and α constituents, but that the change is similar to what occurred on reheating to 500° C. one of the specimens that had been heated and quenched from 700° C. or above, for by such treatment the β constituent gradually diminishes, and the α constituent increases. Careful microscopic examination of the β constituent in the long-heated alloy failed to detect any clear evidence of segregated γ, and one is therefore tentatively inclined to hold the view that the β constituent which disappeared simply dissolved in the α, increasing its

total mass and producing the α, with a less amount of copper than 62 per cent.

"B" *Alloy*, heated for 984 hours at 270° C. The structure of this alloy is but slightly different. Some of the α particles appear in globular form embedded in the β constituent, which were not present in the original alloy. The mechanical properties are but slightly different from those of the original annealed bar.

Nos. 1 and 2 bars, heated respectively to 475° and 565° C. Here the structure is that of particles of the β constituent embedded in α, and generally separated from each other. The α is in greater mass, and the amount of β is about the same in both the quenched and air-cooled material. These facts explain why there is little difference in the physical properties of the quenched and air-cooled bars, the quenched bars having a greater tenacity of 0·45 and 0·8 ton respectively than the duplicate bars cooled in air.

Nos. 3, 4, 5, and 6 bars, heated respectively to 675° C., 720° C., 749° C., and 773° C. The proportion of β in the quenched bars increases with the temperature of heating, which accounts for the increased tenacity of the quenched bars, because β is the harder constituent. The elongation decreases considerably, with the appearance of strips of α connecting the larger grains of the same substance. The envelopes of α in No. 6 account for the great weakness. On bending this alloy it was the α constituent which first gave way.

Nos. 7, 8, and 9 bars, heated respectively to 812° C., 833° C., and 860° C. Heated at temperatures sufficiently high to produce homogeneous β constituent, free from any α, these alloys after quenching in water are, as one would expect, of higher tenacity than those heated to, and quenched at, lower temperatures.

No. 8 alloy quenched from 833° C. has a greatly increased tenacity and ductility as compared with No. 6 alloy. The tenacity has risen 6 tons, the elongation 16 per cent., and the contraction of area 11 per cent.

No. 9 alloy, when removed from the furnace, showed signs of incipient melting.

The microstructure of the air-cooled alloys resembled each other, and were all of the banded type, consisting of strips of α separated by β. The same type of structure can be traced in the quenched specimens when highly magnified, which somewhat resembles the martensite structure of highly heated and quenched low-carbon steels. It is possible that had the pieces of metal been smaller and the quenching more sudden, the β constituent would have been more homogeneous. The structure is analogous to that of steels containing 0·20 per cent. carbon quenched in water from 1,000° C. in which the triangular markings, in lighter shape, represent the incipient separation of ferrite, or free iron, from the martensite.

When a bar is heated and cooled alternately for 30 or 40 times in the range of temperature between 600° C. and 700° C., and is cooled slowly after each heating, the independent particles of α constituent increase to a great size, and suggest by their shape a tendency to form idiomorphic crystals. One is not prepared to give a definite reason for this; it is probably due to the very slow cooling after each heating.

Before the larger bars were heated for mechanical testing, small pieces were heated to approximately the same temperatures, and it is remarkable how close the corresponding structures really were. It may be concluded, therefore, that having the structure of 60/40 brass, the temperature of annealing between 500° C. and 860° C. may be judged approximately.

In a bar heated and cooled many times gradationally, the β crystals extended continuously side by side in long parallel columns for a distance of nearly 3in., within the temperature range of 550° C. and 800° C. The crystalline orientation was heterogeneous in the parts of the metal heated above 800° C. and below 550° C. Heating at about 812° C. does not appear to lead to the growth of such large crystals as are formed below 800° C. They do, however, steadily increase in size as the temperature is raised above 800° C. On straining the crystals of β of No. 6, quenched alloy, slip bands appeared.

Summary of Results.—It is sufficient to state that: (1) Cold-drawn Muntz metal is obtained in the most ductile condition by annealing at 430° C. for 3 months. (2) It is dangerous to anneal between 750° C. and 800° C., because the β crystals are liable to become enveloped with α a structural arrangement conducive to brittleness in both chilled and air-cooled material. (3) Heating to between 800° C. and 830° C., followed by quenching, leaves the metal as homogeneous β constituent, which has a tenacity of about 29 tons per square inch, as compared with 26 tons per square inch in the metal annealed at 500° C., with an elongation of 25 per cent. in 2in. (4) Heating to between 800° C. and 833° C. and cooling in air leaves the metal almost as good as it was after annealing at 500° C., and heating the metal at just about 800° C. causes it to re-crystallise into finer grains than are formed at between 500° C. and 800° C. (5) Brass is remarkably immune from oxidation during heating, and only 0·8 per cent. was oxidised on heating for 48 hours at about 860° C. compared with 4 per cent. for copper heated under similar conditions. (6) It is only the zinc which is oxidised on heating Muntz metal, and the scale detached from heated bars consists entirely of pure zinc oxide.

What still requires investigation is: (1) The minimum percentage of zinc, when alloyed with copper, which will prevent the oxidation of the latter during heating. (2) Whether very prolonged heating of 60/40 brass at temperatures below 470° C. will cause it to become pure β constituent, free from α. (3) The correlation of the composition, physical properties, structure, and heat treatment of all the useful brasses. (4) A similar research to what has been done on 60/40 brass, but in which the bars of Muntz metal should be heated before testing for a much shorter period than 48 hours.

The Development of Brittleness in Hard-drawn Brass.—Occasionally brittleness in old brass wires has, in our experience, been noticed, and we have never been able to account for it. Mr. F. Johnson, when discussing the paper on "A New Critical Point in Copper-zinc Alloys," by Prof. H. C. H. Carpenter and Mr. C. A. Edwards,* remarked that it was well known that brass which has been finished hard (that is to say, hardened by mechanical treatment) was susceptible to "age cracking" or "secular brittleness." A remarkable example of this was afforded in a specimen of hard-drawn brass rod, which had been used as a conductor for high-tension electric current through the concrete floor of one of the Cleveland and Durham Power Company's sub-stations. After long use—about three years—these rods began to crack. A number of them were removed and a careful examination made. When removed, the cracks were found to be filled with a bluish-white powder, consisting of nitrates of copper and zinc, which had been produced by the effect of electrical discharge across the air space between the charged rods and the surrounding insulator, which in passing through the air produced the higher oxides of nitrogen, which then attacked the brass. This powder had accumulated in the cracks and had evidently exerted pressure, which would, of course, tend to extend the fractures. The portions of the brass enclosed by the threaded nuts on each end of the bar were perfectly sound and free from incipient cracks—an indication that the bar itself when put to use must have been of the same character. The direction taken by the cracks clearly indicates that it was along the planes of weakness produced by cold drawing, for they travelled in such a way as to produce the well-known cup and cone fracture, often seen in so-called "cuppy steel wire" sometimes the result of overdrawing. Overdrawing leaves the metal weak along conic surfaces, and when the reduction of area is too great, fractures of the cup and cone type occur when passing through the draw plate. If the reduction of area is just insufficient to cause rupture, the internal stresses must be excessive. The conductor rods when in use were in a constant state of tremor, and there can be no doubt that where they were not securely held at the ends by the screwed nuts, this tremor gave impetus to internal rupturing, and eventually caused the rod to break into pieces.

The analysis of the brass rod was as follows: Copper 58·61 per cent., zinc 38·61 per cent., lead 2·40 per cent., tin 0·25 per cent., iron 0·08 per cent.—total 99·95 per cent. The presence of lead is conducive to weakness, and it is possible that had lead been absent failure would not have occurred.

* "Journal of the Institute of Metals," 1911, No. 1., Vol. V., page 179.

The hardness by Brinell's machine was 119, and on heating to 440° C. for one hour it fell to 109; but after heating to 700° C. for one minute and cooling, this fell to 77, or a drop of 42 hardness degrees, showing that all the hardness produced by cold working was removed by this simple treatment, and we have no doubt that had the rods been so heated before being put into use the internal stresses would have been destroyed, and in spite of the lead present the bars would not have broken down.

THE UTILISATION OF SOLAR ENERGY.

A PAPER on the above subject was read before the Society of Engineers (Incorporated) on Monday, the 6th inst., by Mr. A. S. E. Ackermann, B.Sc., who has been associated with the work (as joint consulting engineer with Mr. C. T. Walrond, to the Sun Power Company and the Shuman Engine Syndicate) for nearly four years. The paper deals with the whole of the experiments which have been made during the four years, and which have cost about £30,000. After referring to the principal workers in this field, the author gave determinations of the solar constant and dealt fully with the varying percentages of this quantity that were available throughout the day for power purposes. He then described four types of Shuman sun heat absorbers, and gave in great detail the results of his 48 trials of these absorbers, the latest pattern (that erected near Cairo, Egypt) of which gave a maximum thermal efficiency of no less than 40·7 per cent., and a maximum output of steam of 1,442lbs. per hour at a pressure of 15·8lbs. per square inch absolute. The results of these types of absorbers were compared by means of tables and curves, and from these the author had constructed a formula by means of which it was easy to calculate for a given type and size of absorber the total output of steam per hour if three things were known: (1) the time of day; (2) the humidity; and (3) the steam pressure. It had been known that humidity adversely affected the quantity of solar radiation arriving at the earth's solid surface, but this was the first time that its effect on solar steam production had been quantitatively determined.

The difference between the thermal efficiency of the solar boiler and the commercial value of the steam produced was brought out, the author making it clear that in the case of such low-pressure boilers a high thermal efficiency was not necessarily the same thing as the most economical conditions of working, and he showed that, up to a certain limit, the higher the steam pressure, the more economical the working, though the thermal efficiency was then lower. Two of the types of absorber did not move with the sun, and one did. The greater constancy of output of steam in the case of the latter was very marked. In order to utilise the low-pressure steam economically, Mr. Frank Shuman designed a special engine which had also gone through several stages. This engine was fully described with drawings and the author gave the results of his 14 trials of the several engines and compared their results with those of exhaust steam turbines and the low-pressure cylinders of compound and triple-expansion engines, showing that the Shuman engine was the more economical. The steam consumption of one of these engines was only 22·1lbs. per brake horse-power hour, when the output was 94·5 b.h.p., and the steam pressure only 16·2lbs. per square inch absolute. The thermal efficiency of the engine compared with an engine working on the Rankine cycle was 54·75 per cent. In the case of a Shuman high-pressure non-condensing engine with an output of 29 b.h.p., the steam consumption was 23·8lbs. per brake horse-power hour and the relative thermal efficiency 71·7 per cent. Finally, the author gave the results of his trials of the complete sun power irrigation plant at Cairo, and described his design of a special form of weir tank for measuring greatly differing quantities of water.

International Congress of Consulting Engineers.—We are informed that the second International Congress of Consulting Engineers is to be held in Berne, Switzerland, from July 15th to July 22nd. The first was held last year in Ghent, Belgium. It is proposed to hold the third in San Francisco in September, 1915.

THE ELASTICITY AND ENDURANCE OF STEAM PIPES.*

BY C. E. STROMEYER.

IN 1909 I read a paper before this institution on "Steam Pipe Explosions Due to Water-hammer," in which the nature of about 100 of these explosions, as reported by the Board of Trade Surveyors, was analysed. In the present paper it is proposed to extend the enquiry into the causes of steam pipe failures by dealing with another batch of about 100 reported explosions which have been attributed to fatigue and to want of elasticity, though it may have to be admitted that bad material and workmanship, including injudicious or unnecessary annealing, have occasionally either accelerated the failures or have been their chief causes.

In dealing with this subject it will first of all be necessary to fix on a standard of comparison for the fatigue stresses which may have caused the failures; but in order not to complicate this subject, and also because definite information is not available, it will for the present be assumed that Guest's law for steel also applies to copper, which means that the circumferential stresses in pipes, due to internal steam pressures, do not affect the bending stresses which in the cases under consideration have caused the fractures. Then, also, nothing is as yet known about the influence of temperature on the power of copper to resist fatigue stresses, though it is probable that it has a weakening effect; but temperature also increases the elasticity of copper, so that as regards deformations due to fatigue stresses no serious error will be committed by leaving these two temperature influences out of account.

According to experiments which were mentioned by me in the discussions on Dr. Stanton's paper (Proc. Inst. Civil Engineers, 1911, Vol. CLXXXVIII., page 35) and on Messrs. Eden, Rose, and Cunningham's paper (Journal Inst. Mechanical Engineers, 1911, Vols. III. and IV., page 884), the relationship between the fatigue stresses ($\pm S$) and the number (N) of the stress cycles (revolutions) which cause fracture is expressed by the formula—

$$\pm S = Fl + C\,(10^6 : N)^{\frac{1}{4}}.$$

Here C is a constant depending on the nature of the material and F*l* is the fatigue limit of the material. Both F*l* and C had been obtained by breaking a number of samples by fatigue stresses, and marking off the test results on diagrams in which the ordinates were spaced so as to represent $(10^6 : N)^{\frac{1}{4}}$. The test results were then found to lie on straight lines which, when prolonged, cut the zero ordinate at the heights F*l*, which were then adopted as being the fatigue limits. These tests could naturally not have been continued to an infinite number of revolutions, and there was therefore no absolute certainty that this exterpolated fatigue limit was a reality until, by improved methods of testing, this point was firmly established. In other words, more recent experiments have demonstrated the fact that the above formula applies not only within the range of previous experiments, say, from two thousand to 20 million alternations of stress, but also to an infinite number. Wöhler's experiments and, in fact, all past experiments which have been examined, confirm the above-mentioned formula. His experiments confine themselves to steels, except one solitary series of tests on wrought iron, but they have been extended by me so as to embrace, at least as regards torsion fatigue tests, about 50 different qualities of steels and steel alloys, cast and wrought iron, nickel, copper, aluminium, phosphor bronze, magnalium, and other alloys, and in all cases the test results harmonised with the above formula, which may therefore be accepted as being correct. A matter of even greater importance than the general form of the formula is that the fatigue limit can now be expeditiously determined with greater accuracy even than the static tenacity. In one case its extreme values amongst eight test pieces cut from one crank shaft differed by less than ± 0·4 per cent. of the mean value.

Unfortunately no bending fatigue tests have been carried out on copper, but this omission will be made good in the near

* Paper read at the spring meetings of the fifty-fifth session of the Institution of Naval Architects, April 2nd, 1914.

future, and the determination of the fatigue stresses which caused fractures in copper pipes will therefore have to be based on deductions drawn from a few torsion fatigue tests on copper bars which are summarised in the following formulæ, in which $\pm S_t$ is the alternating shearing stress due to torsion strains which causes failure at the Nth revolution.

Copper bar as rolled	$\pm S_t = 5{\cdot}4 + 0{\cdot}37\ (10^6 : N)^{\frac{1}{4}}$
Copper bar as rolled	$\pm S_t = 5{\cdot}6 + 0{\cdot}51\ (10^6 : N)^{\frac{1}{4}}$
Ditto, mean of above	$\pm S_t = 5{\cdot}5 + 0{\cdot}44\ (10^6 : N)^{\frac{1}{4}}$
Copper bar annealed in vacuo ..	$\pm S_t = 2{\cdot}55 + 0{\cdot}87\ (10^6 : N)^{\frac{1}{4}}$
Ditto, annealed and chilled in water	$\pm S_t = 2{\cdot}69 + 0{\cdot}97\ (10^6 : N)^{\frac{1}{4}}$

It having been found that on an average the bending fatigue limit for steel is about 60 per cent higher than for torsion,

TABLE I.

Basic Steel.	Fatigue limit. Tons per square inch.	Values of C. Tons per square inch.
British ordinary	9·69	4·53
British dead soft	11·26	3·92
German ordinary	11·34	4·10
German dead soft	8·94	4·79
Mean for mild basic steel	10·31	4·33

qualities, which contain about 0·20 per cent. carbon. This is due to the presence of varying percentages of nitrogen, which element has a tenfold greater influence than carbon on

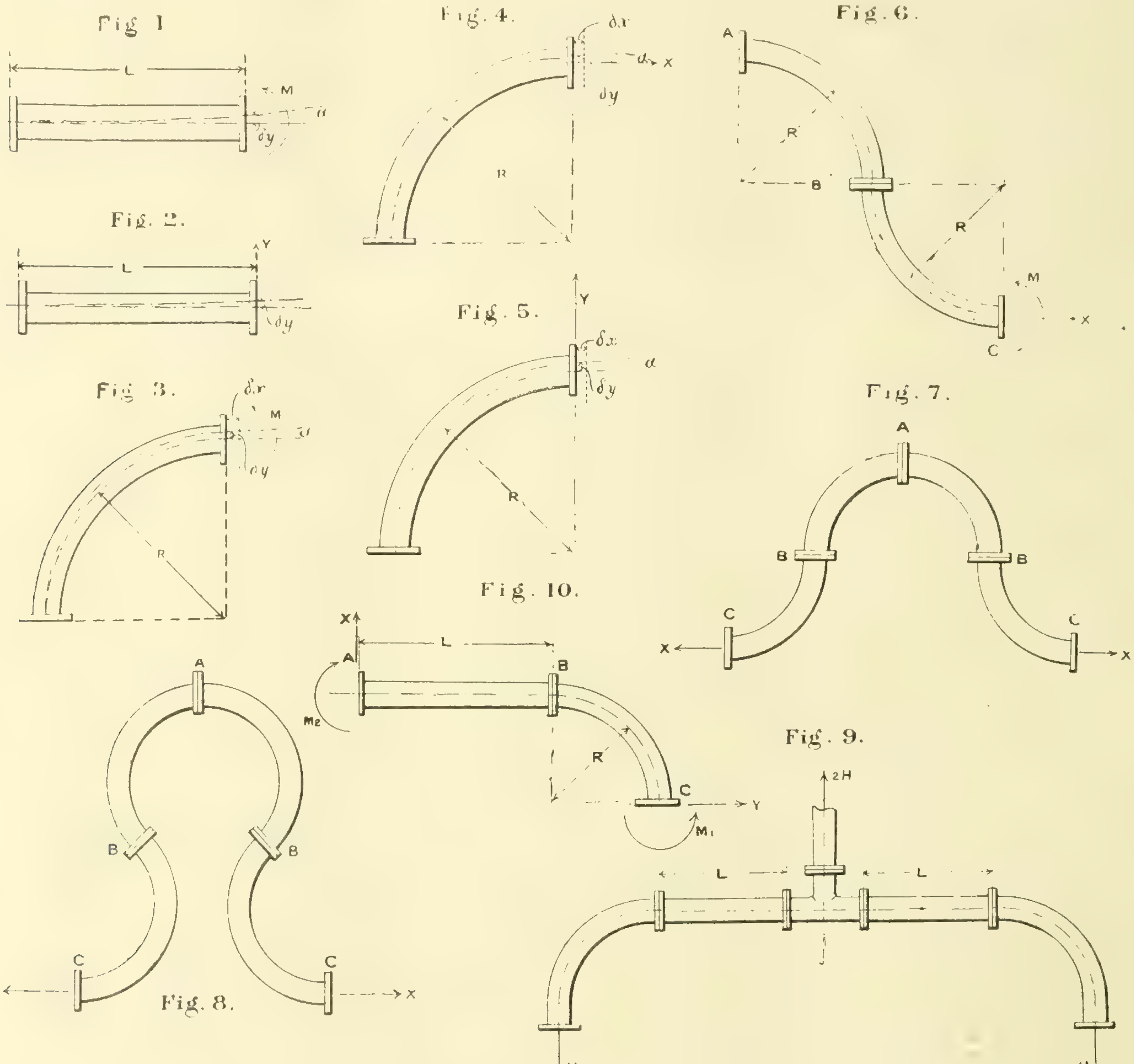


Fig. 1. Fig. 2. Fig. 3. Fig. 4. Fig. 5. Fig. 6. Fig. 7. Fig. 8. Fig. 9. Fig. 10.

the last of the above torsion fatigue limits may reasonably be increased from 2·69 to 4·30 tons per square inch for the bending fatigue limit for copper, and, seeing that the same comparative tests on steels show that the value of C for bending is three and a half times as great as that for torsion, the value of C = 0·97 may be increased to 3·4 tons per square inch and the formula for the bending fatigue stresses of copper is probably

$$\pm S_b = 4{\cdot}3 + 3{\cdot}4\ (10^6 : N)^{\frac{1}{4}}.$$

Seeing that wrought iron and mild steel pipes are now largely used on steamers, formulæ for their bending fatigue stresses will also be of interest. Amongst my own tests I find the following results for basic steel, which is the quality of which many welded steel pipes seem to be made.

It will be noticed that the fatigue limit for the softer qualities of basic steel, which contain about 0·10 per cent. carbon, are not necessarily lower than those for ordinary mild the fatigue limit. The fatigue limit for cast steel is only a little higher than the above, viz., about 12 to 13 tons per square inch. The formula for the bending fatigue stresses of mild steel may therefore be written—

$$\pm S_b = 10{\cdot}30 + 4{\cdot}33\ (10^6 : N)^{\frac{1}{4}}.$$

Only one set of bending fatigue tests has yet been carried out on wrought iron (by Wöhler). The results can be expressed by the formula

$$\pm S_b = 6{\cdot}73 + 4{\cdot}43\ (10^6 : N)^{\frac{1}{4}}.$$

Amongst the Board of Trade reports on steam pipe failures there are none which may be attributed to fatigue of mild steel, but there are a fairly large number of failures of copper pipes, of which a few are capable of being analysed with the help of the above formula. The following are the

report numbers of the failures in question. Failures said to be due to vibrations:—

Straight Pipes.—Nos. 948, 1,113.

L *Bends* like Fig. 6.—Nos. 453, 854, 945, 958, 1,024, 1,049, 1,057, 1,095, 1,111, 1,164, 1,181, 1,187, 1,207, 1,291, 1,296, 1,491, 1,516, 1,611, 1,688, 1,904, 1,941, 1,954.

U *Bends* like Fig. 10, without Central Branch.—Nos. 480, 1,011, 1,021, 1,069, 1,172, 1,185, 1,313, 1,426, 1,435, 1,501, 1,922, 2,105.

U *Bends* with Central Main Pipe, like Fig. 10.—Nos. 970, 992, 1,015, 1,036, 1,696.

S Bends and also two L Bends placed at right angles to each other.—Nos. 657, 718, 749, 772, 775, 915, 1,290, 1,527, 1,654, 1,709, 1,926, 1,993.

Expansion Bends with Straight Lengths. Nos. 767, 943, 1,616, 1,651, 1,795, 1,852, 1,895, 1,931.

The following failures are probably due to looseness of the engine or the boilers:—

Engine Seatings Loose.—Nos. 742, 833, 1,013, 1,160, 1,355, 1,443, 1,666, 1,922, 1,964, 2,021, 2,088. In these cases it is probable that the movements were both as large and as numerous as the revolutions of the engines, which on an average may be assumed to be 60 per minute for six months per annum.

Boilers Loose.—Nos. 543, 728, 1,210, 1,467. In these cases it is probable that the movements were large but few, and the empirical rule for fatigue stresses does not apply.

Relative movement between boilers or engines and the ship's structure. Nos. 1,268, 1,543, 1,291, 2,176.

Shaft Broke and Engine Raced Violently.—No. 1,216. This pipe had many bends, otherwise the stresses might have been estimated.

Most of the above-mentioned cases cannot profitably be analysed on account of complexity of form and absence of details. However, Nos. 958, 1,049, 1,181, and 1,954 of the first group and Nos. 1,355, 1,543, 2,021 of the second group are suitable for this purpose. It will first of all be necessary to obtain an approximate estimate with the help of the above fatigue stress formula for annealed copper as to the intensities of the fatigue stresses which caused the failures, and, subsequently, these stresses will be used for estimating the probable relative movements of the ends of the failed pipes.

The estimated fatigue stresses which fractured the above-mentioned ten pipes are contained in Table II. As already mentioned, no allowances have been made for the internal steam pressures and their temperatures, though it may be mentioned that with the exception of 2,021, for which the steam pressure was 200lbs. per square inch, the pressures in all the cases were 160lbs. per square inch. Case No. 1,954 (2) deserves special attention, for the estimated fatigue stresses are approximately equal to the static tenacity of copper. The very fact that this pipe withstood these alternative stresses for four hours suggests, either that the adopted value of C = 3·4 tons per square inch per 1,000,000 revs. is too high, or that the copper was of a harder quality than usual.

Amongst the 200 cases of steam pipe explosions reported on by the Board of Trade, only three reports have been found in which measurements of movements which may have caused the failures are given. Report No. 1,467 mentions that the boiler rolled $\frac{1}{2}$in. Report No. 1,296 mentions that when getting up steam the length between the two valves (no dimensions given) shortened by 0·47in., and the difference of level between the two valves altered by 0·44in., the boiler top having risen $\frac{9}{16}$in. as compared with the ship's structure and the engine stop valve, which had risen $\frac{1}{8}$in. The history of this pipe is interesting. It was made of solid drawn copper, and, fitted in July, 1899, it cracked near its flange 17/1/1900 ($5\frac{1}{2}$ months' interval). The cracked end was cut off and replaced by a sleeve, which cracked nine hours after lighting fires. A new sleeve of thicker copper ($\frac{1}{4}$in.) was now fitted, which ran, say, from the end of February to July 30th, 1900 (about 5 months), and cracked. A new pipe with a larger bend was now fitted (August, 1900), but it burst on December 12, 1900 (say, four months), and killed three men. An expansion gland was now fitted, but it did not work, and the pipe cracked again (no data given). The crack was repaired and the gland made workable.

These several failures seem to have been due not to frequent movements associated with the revolutions of the engine, but to steady stresses caused by the difference of expansion of the boiler and engine, intensified no doubt by the vibrations of the engine. No experimental data as to the endurance of copper under these conditions are yet available. No. 1,318 reports that the boiler top rose up $\frac{9}{16}$in. and the engine $\frac{1}{4}$in. due to the raising of the steam pressure, the two boilers separated by $\frac{1}{8}$in., and the distance between the engine and one boiler stop valve was reduced by $\frac{3}{16}$in. In this case the explosion was due to imperfect brazing of one of the flanges.

In order to understand the stresses which arise when pipes are strained, the several possible deformations of straight and curved pipes, as represented in Figs. 1 to 5, have been expressed mathematically in Table III.

TABLE II.—*Estimated Fatigue Stresses under which Certain Copper Pipes Failed after N Repetitions.*

Report Number.	Age at Time of Fracture.	Assumed No. of Revolutions.	$(10^6 : N)^{\frac{1}{4}}$	Estimated Fatigue Stresses. Tons per sq. in.	Remarks.
		Failures due to Vibrations of the Engines.			
958 (1)	12 months	15,000,000	0·505	6·02	Starboard pipe.
958 (2)	25 months	31,000,000	0·423	5·71	Port pipe.
1,049 (1)	$2\frac{1}{2}$ years	40,000,000	0·397	5·65	First failure.
1,049 (2)	1 year	15,000,000	0·505	6·02	Second failure.
1,181 (1)	10 years	150,000,000	0·285	5·27	First failure.
1,181 (2)	24 hours	86,000	1·846	10·57	Heavy weather.
1,954 (1)	$8\frac{1}{3}$ years	120,000,000	0·302	5·33	First failure.
1,954 (2)	4 hours	14,000	2·900	13·85	Engines racing.
		Failures due to Loose Engine Seatings.			
1,355	35 months	44,000,000	0·388	5·62	Long bend.
1,543	4 years	60,000,000	0·359	5·52	U bend secured to deck beam
2,021	3 years	45,000,000	0·386	5·61	Long bend.

TABLE III. (*Figs. 1–5.*)

	Estimated Inclinations. α	Estimated Displacements. δx.	δy
Fig. 1	$+M.L:E.I$ ..	——	$+\frac{1}{2}M.L^2:E.I$
Fig. 2	$+\frac{1}{2}Y.L^2:E.I$		$+\frac{1}{3}Y.L^3:E.I$
Fig. 3	$+\frac{1}{2}\pi M.R:E.I$	$-0·571\,M.R^2:E.I$	$+M.R^2:E.I$
Fig. 4	$-0·571\,X.R^2:E.I$	$+0·356X.R^3:E.I$	$-\frac{1}{2}X.R^3:E.I$
Fig. 5	$+Y.R^2:E.I$ ..	$-\frac{1}{2}Y R^3:E.I$	$+\frac{1}{4}\pi Y.R^3:E.I$

M is the external bending moment shown in Figs. 1 and 3.

X is the external horizontal pull shown in Fig. 4.

Y is the external vertical pull shown in Figs. 2 and 5.

E is the modulus of elasticity. Say, 13,000 tons per square inch for wrought iron and steel, 8,300 for copper, and 4,500 to 8,000, or, say, 6,000, for cast iron.

I is the moment of inertia of the section of the pipe, and is equal to $(D^4 - d^4)\,\pi : 64$, where D is the external and d the internal diameter of the pipe.

S_b the maximum bending stress for any moment. M is $\frac{1}{2}$ M . D : I, which expression can be introduced in the formulæ when the movements produced by X and Y are known.

a, δx, and δy are the acquired inclination and the displacements of the ends of the pipes (*see* Figs. 1-5).

One application of these formulæ can be illustrated with the help of Fig. 6, which represents half a U bend. Assume, as was the case in Prof. Bautlin's experiments, which will shortly be dealt with, that the flange A, which is the middle of the bend, is a fixture, and that a pull X is acting horizontally on the flange C. Then the bending of B C is the same as that in the curved pipe in Fig. 4, X being applied as in that figure. The bending of A B is represented by the two cases Figs. 3 and 5, M being equal to X R, and Y equal to X. Then the acquired inclination a of the flange B is as per third and fifth line of Table III.—

$$a = (\tfrac{1}{2}\,\pi\,R\,.\,X\,.\,R + X\,R^2) : E\,.\,I = 2{\cdot}571\,X\,.\,R^2 : E\,.\,I.$$

The displacement $\triangle$ of the flange C is the sum of the displacement δy of Figs. 3 and 5, of δx of Fig. 4, and of the product of the inclination a into the radius R of the bend B C

$$\triangle = (X\,.\,R^3 + 0{\cdot}785\,X\,.\,R^3 + 0{\cdot}356\,X\,.\,R^3 + 2{\cdot}571\,X\,.\,R^3) : E\,.\,I = 4{\cdot}713\,X\,.\,R^3 : E\,.\,I.$$

The bending moment at A is, of course, 2 H.R, and this is equal to S . I : $\frac{1}{2}$ D, where D is the external diameter of the pipe. On replacing I by X 2 R . D : 2 S, the stress S at the flange A can be expressed in terms of the displacement $\triangle$

$$S = \triangle\,.\,D\,.\,E : 4{\cdot}712\,R^2.$$

For copper the value of E is about 8,300 tons per square inch, so that for pipes of this material $S = 1{,}750\,\triangle\,.\,D : R^2$, and, assuming 4·3 tons per square inch as being the fatigue limit for copper, the maximum permissible movement of half a copper U bend (Fig. 6) should not exceed

$$\triangle_c = R^2 : 405\,D.$$

For steel and wrought iron E = 13,000, and therefore $S = 2{,}750\,\triangle\,.\,D : R^2$, and, assuming the fatigue limit for wrought iron to be 6·75 tons per square inch, we have

$$\triangle_i = R^2 : 410\,D \text{ for wrought iron.}$$

Assuming a fatigue limit of 10·3 tons per square inch for mild steel, we have

$$\triangle_s = R^2 : 2.5\,D.$$

Thus a U bend (Fig. 7) of 8in. diam. and 8ft. high, which forms part of a long length of pipe, will take up the following expansion movements without injury to itself: 1·40in. if of copper, 1·40in. if of wrought iron, and 2·20in. if of mild steel.

(*To be continued.*)

CENTRAL EXHAUST STEAM ENGINES.

THE accompanying illustrations show diagrammatically two arrangements of steam engine cylinders provided with central exhaust, the invention of Mr. P. Smal, Couthuin, Belgium. In Fig. 1 the central exhaust is controlled by the engine piston and in Fig. 2 by a rotary valve. The engine is arranged to work non-condensing or condensing, either by means of the central exhaust ports only or by means of the combined central exhaust and slide valve exhaust, or it may work by its central exhaust with a clearance reduced to a minimum during the admission period and enlarged during the compression period.

Referring to Fig. 1 the long piston B in the cylinder A controls the central ports C. The steam admission is performed by the cylindrical slide valve D, comprising two balanced pistons between which a chamber H is provided. The admission is controlled as usual by the outer edges of the pistons, whilst the exhaust is controlled by the inner edges. E is a duct through which the exhaust steam is discharged into the atmosphere or into a condenser. This duct may be closed at will by means of the stop valve F. The device works as follows: When the engine is running in the usual manner the stop valve F is closed and the steam escapes through the central exhaust port C; the clearances having been calculated in order to be as small as possible. But if the engine works condensing (the clearances being reduced to a minimum), it may in certain cases be necessary to work non-condensing. In such cases the central exhaust arrangement cannot be used owing

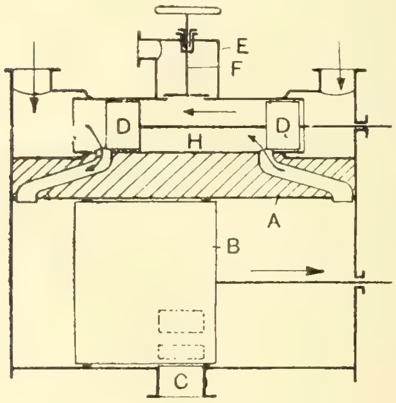


FIG. 1.

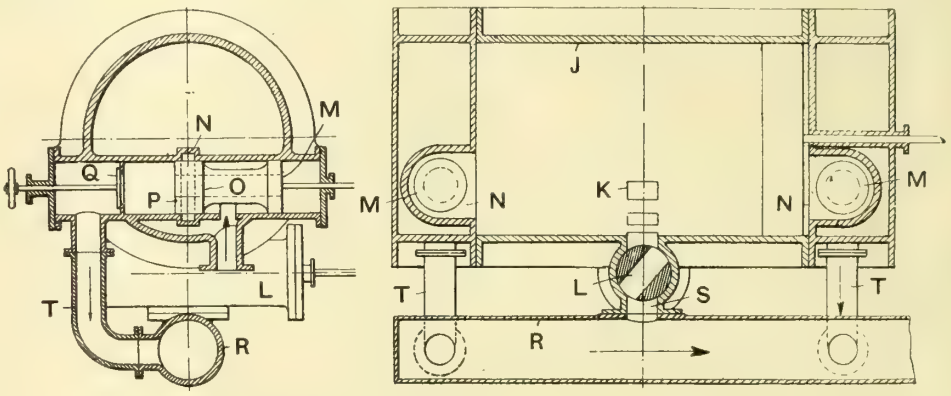


FIG. 2.

CENTRAL EXHAUST STEAM ENGINE.

to the resulting high pressure within the very small clearances. By lifting the valve F the exhaust steam will, however, escape into the atmosphere through the slide valve with a resulting compression which is always lower than that from the central exhaust. On the other hand, when the motor works condensing and with central exhaust only, that is to say, when the valve F is closed, it is obvious that during the long compression of the central exhaust, the whole chamber H between both pistons D is added to the clearance of the cylinder until both pistons D close the ducts between the cylinder and space H. In such cases the long compression resulting from the central exhaust is reduced according to the size of the space H, without increasing, at the beginning of the admission period, the clearance of the cylinder and its cooling surfaces. Engines provided with central exhaust may thus work with low admission pressure by reducing to a minimum the clearance of the cylinder. The steam contained in the chamber H during the compression period escapes during the following stroke of the piston, when the slide valve again connects the chamber H with the cylinder, and the steam may work usefully within the cylinder, provided the connection is established again before the central exhaust takes place. This may be obtained by shortening or eliminating the inside laps of the pistons of the slide valve D.

In Fig. 2 the central exhaust of the cylinder J is shown at K; the exhaust is controlled by means of a rotary valve L, which opens and closes the ports K in order to produce the exhaust lead and the compression. A balanced slide valve M is provided at each end of the cylinder J and controls a port N connecting the slide valve with the corresponding side of the cylinder. The edge O of the piston of the slide valve

M effects the admission whilst the exhaust is effected by means of the edge P of the piston. The exhaust operated by the slide valve is controlled by a stop valve Q, which is shown in the closed position. The exhaust steam from the central exhaust flowing through pipe S and the exhaust steam from the slide valve exhaust flowing through pipe T is collected in the pipe R which opens into the atmosphere or into the condenser. The working of this arrangement is similar to the one previously described.

INSTITUTION OF NAVAL ARCHITECTS.

The spring meetings of the Institution of Naval Architects opened on Wednesday last week in the hall of the Society of Arts, Adelphi, London. The Marquis of Bristol, who presided, was re-elected president. The annual report of the Council for the past year recorded a further increase in the membership of the Institution. A cordial invitation had been received from the North-east Coast Institution of Engineers and Shipbuilders to hold a summer meeting in Newcastle-upon-Tyne this year, which the Council had accepted. The Institution of Engineers and Shipbuilders in Scotland will, it is understood, also take part in this meeting. The Elgar Scholarship for 1914 was awarded last summer to Mr. R. J. Monk, of H.M. Dockyard, Chatham, but on his appointment to an Admiralty Cadetship, the scholarship was given to the second candidate in order of merit, Mr. F. W. Thorne, of H.M. Dockyard, Portsmouth. The Post-Graduate Scholarship in Naval Architecture had this year been awarded to Mr. C. Frodsham Holt, of Liverpool University. The annual gold medal and premiums for the past year had been awarded as follows: The gold medal to Mr. G. S. Baker, late R.C.N.C., for his paper on "Methodical Experiments on Mercantile Ship Forms." Premiums to Mr. A. Cannon, for his paper on "The Effect of Loose Water upon the Rolling of a Ship" and to Mr. L. Woollard, R.C.N.C., for his paper on "The Effect of Water Chambers on the Rolling of Ships." The movement set on foot last year for the establishment of a permanent memorial to the late Sir William White had met with a satisfactory response. A general committee had been formed, with Earl Brassey as chairman, and a total of over £2,200 had been subscribed or promised; the committee were now considering the form which the memorial should take. The results of the elections to the Council were intimated by the secretary, Mr. Dana. Mr. R. Saxton White had, it was stated, been appointed a vice-president. The following had been elected to the Council to represent ordinary members: Prof. Abell, Mr. C. Buchanan, Mr. James Gilchrist, Mr. James Hamilton, Dr. G. B. Hunter, Mr. W. J. Luke, Mr. Herbert Powell, Mr. A. E. Seaton, and Mr. W. H. Whiting. The successful candidates for the representation of associate members had been, it was announced: Prof. Dalby, Admiral Sir H. B. Jackson, and Mr. Alexander Richardson.

The Marquis of Bristol, in the course of his presidential address, said that the Institution's record of work accomplished during the past year had been characterised by considerable activity. The world-wide interest taken at the present time in questions relating to shipbuilding was a significant proof of the deep and far-reaching influence exerted by this branch of engineering upon the commercial and industrial development of nations. Our leaders of science were constantly clamouring for more ample resources, not only to carry out research work, but also to discover and encourage talent, and to train the men to whom the future looked to carry on the great work of the masters of the past. Every civilised country now recognised the need of such assistance, and many foreign Governments contributed more liberally than ours in proportion to the extent of their industrial interests; indeed, the funds allocated to such purposes did not by any means correspond to the wealth of the nation, or to the importance of the interests at stake. Much had been done in the past, but still more remained to be done. Lord Haldane, in a recent article, had stated that England was nearer three decades than one behind both Germany and the United States in the recognition of the value, and in its provision, of the apparatus of scientific instruction and research. Lord Haldane had, no doubt, carefully studied the question, both in this country and abroad, and his statement was one that deserved serious consideration, when we reflected what it meant at the present time for a nation to be behind hand in its intellectual equipment. Every year competition grew keener, and the value of scientific knowledge in comparison with a mere general experience of earlier methods became of greater moment, and while Lord Haldane's utterance might appear unduly pessimistic in view of the great steps that had been taken within recent years to provide facilities for technical education and research, yet we must bear in mind that for these establishments to be worthy of a great Empire, the responsible heads of Government departments and the governing bodies of educational centres must needs keep continually alert to meet changing conditions, and to provide, not only for the immediate necessities of the moment, but for the inevitable expansion in new directions for which we must be prepared if success was to attend our efforts. At the National Physical Laboratory much good work of a practical kind, bearing upon the industrial problems of the day, was being carried on. The Froude Tank was meeting with the recognition which it deserved at the hands of shipbuilders, who were making each year a better use of the facilities which it afforded for independent tests of models. In its other aspect, of enabling research work to be carried out, it had also fully justified the hopes that were entertained of the measure of its ultimate usefulness.

Turning to the actual results of the past year's shipbuilding operations, these were, he remarked, of special interest. Without going too deeply into figures and statistics there were two main considerations: First, the increasing severity of competition from other countries engaged in shipbuilding; and secondly, the extent and variety of new construction, which included not only the many varieties and types of ships, but also the new methods of and improvements in propulsion which had been evolved in recent years. Both in naval and merchant ships the great increase of size that had taken place gave rise in itself to many new problems, and called for knowledge of a kind that previous experience could not alone supply. The progress made with the motor-ship had, notwithstanding early difficulties, been noteworthy, particularly on the Continent. In our own country, however, it had suffered something of a check owing to a number of causes, the dominant factor being the distribution of the oil supplies of the world, and the uncertainty in the minds of shipowners as to the future of this industry from the commercial side. Although the gradual elimination of mechanical difficulties was placing the problem of the motor-driven ship of medium size in a much more favourable light than before, yet the question of supplies and cost of oil was still one that needed a more satisfactory answer than could yet be given before owners were likely to embark on a large scale upon the new means of propulsion. Meanwhile, the geared turbine continued to make good the forecasts of its supporters, and its use was now being widely extended both in numbers and size. The aggregate horse-power of mechanically-geared marine turbines was, according to information supplied to the author, upwards of 634,000 h.p., and individual installations of as large as 14,000 h.p. were now under construction for the mercantile marine and still larger units for naval vessels. The reliability of the turbine and its smooth-running and labour-saving advantages had already established it firmly in favour with shipowners, and the additional advantage of economy gained by the mechanical gearing made it now undoubtedly hard to beat for most forms of marine propulsion.

In conclusion, he referred to last year's work of the International Conference on the Safety of Life at Sea. The terrible calamity which overtook the "Titanic" on her maiden voyage had in the end been productive of an exhaustive enquiry and a subsequent Conference which had effected a very necessary revision of the rules governing the mercantile fleets of all nations for the safety of life at sea. So swiftly had changes succeeded each other in the near past, and so rapidly had merchant ship construction developed in point of size, speed, and complexity of internal arrangements that practice had outrun the compass of existing regulation. The great loss of life in the "Titanic" disaster brought home in a manner which nothing else could have done the urgent need of revision.

TRIALS OF A SMALL DIESEL ENGINE.*

BY PROF. W. E. DALBY, M.A., B.SC., F.R.S.

THIS paper records the results of some trials made by the author on a 10 h.p. Diesel engine in the laboratory of the City and Guilds (Engineering) College. The novelty of these trials lies in the indicator diagrams, which are relatively large, and were taken photographically by means of an optical indicator devised by the author, and show the action in the cylinder with accuracy.

Fig. 1 is a diagram, not to any scale, showing the general arrangement of the engine with its accessories. The central area of the diagram is occupied by the cylinder and shows the air admission valve, the exhaust valve, and the fuel valve which admits the supply of oil fuel to the cylinder. These valves are opened by levers operated by a half-speed cam shaft and are closed down on their seatings by springs. There is also a separate starting valve controlled by a separate lever and a cam on the half-speed shaft; this valve lies behind the fuel valve, but is not shown on the diagram. The supply pipe connecting the starting valve to the store bottle through the regulating valve B is, however, indicated. To start the engine, the lever which operates the fuel valve is put temporarily out of action so that the fuel valve keeps closed; the regulating valve B is opened, and for a few revolutions the engine runs on compressed air drawn from the store bottle. After the normal speed is reached, valve B is closed, valve C is opened, and the lever controlling the fuel valve is thrown into action, oil is admitted, and the engine then works normally.

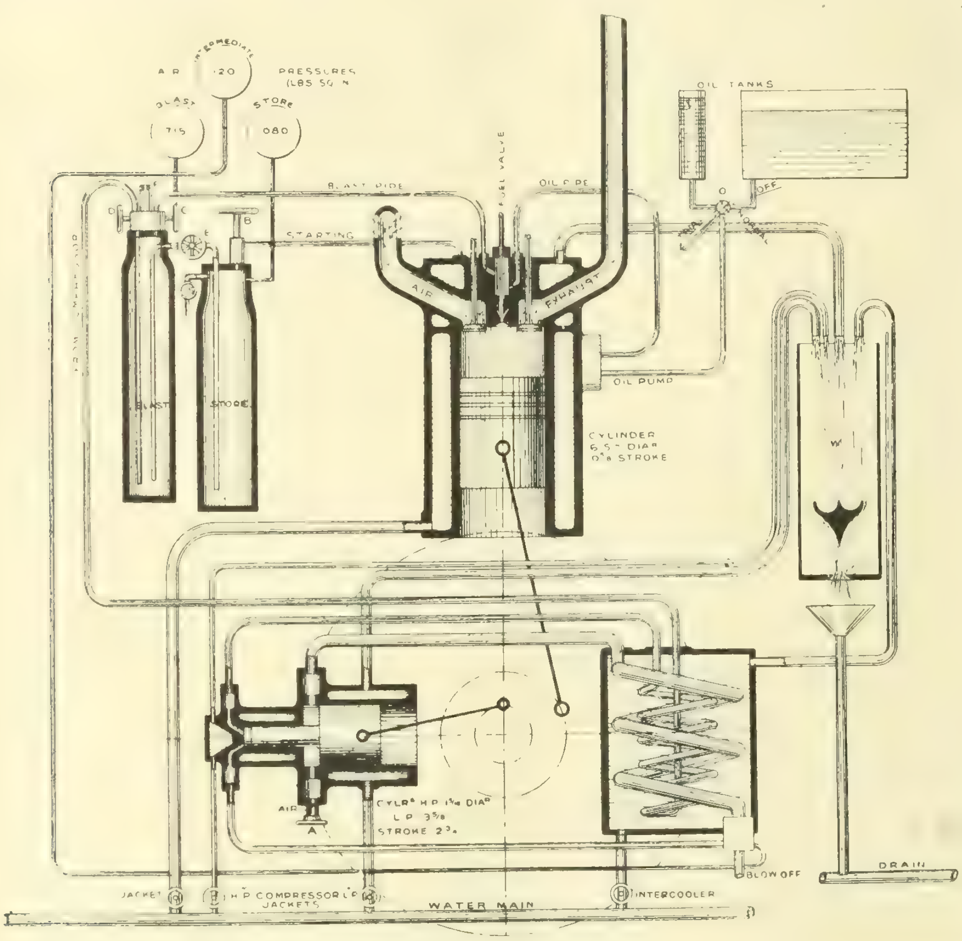


FIG. 1.—DIAGRAM OF DIESEL ENGINE.

The oil supply is contained in a tank placed about 6ft. above the pump. The pump forces the oil into the annular space round the fuel valve, against the blast pressure which is continuously maintained there in virtue of its connection with the blast bottle through the blast pipe and the regulating valve C. Then, when the fuel valve is opened, the blast pressure blows the oil through the narrow passage ways surrounding the nose of the fuel valve, into the clearance space of the cylinder. The difference between the pressure in the annular space and the pressure in the clearance space is considerable, and the energy corresponding to the difference is utilised in reducing the oil to a fine mist.

Air for the blast is compressed by a two-stage water-jacketed compressor driven from the crank shaft, and after each stage of the compression the air flows through a cooler, as illustrated in the diagram. Air is drawn into the compressor at A. A, in fact, is a cap by means of which the size of the opening can be varied, and in this way the quantity of air delivered to the bottles can be regulated. These bottles are placed in communication with one another through the valve E. Air is delivered to the blast bottle from the compressor through the valve D, and then, if it is also necessary to replenish the stock in the store bottle, the valve E is opened and part of the delivery flows across into store to be used later for starting the engine; the other part maintains the supply in the blast bottle against the intermittent flow through the fuel valve. The pressure of the supply to the fuel valve is regulated by the valve C. In one of the experiments described below the pressures were: In the bottles, 1,080lbs. per square inch; in the blast pipe, 715lbs. per square inch; and at the intermediate stage between the low-pressure and high-pressure cylinders of the compressor, 120lbs. per square inch. Four pipes are taken from the water main to respectively supply water to the jackets of the engine cylinder, the jacket of the high-pressure cylinder of the compressor, the jacket of the low-pressure cylinder of the compressor, and to the intercooler. The discharge from all the jackets is collected in an orifice tank W, so that the quantity of water flowing through the plant can be measured by observations of the head over the orifice.

A section through the fuel valve is shown in Fig. 2. Oil from the force pump is delivered through the channel O, and air enters through the channel A. When the fuel valve is opened the air forces the oil through the narrow winding passages which obstruct its free entry into the clearance space in the cylinder. The valve itself is a steel spindle B, closing down on to a conical seating S, giving access to the clearance space of the cylinder through a hole about $\frac{1}{20}$in. diam. The spindle passes through a gun-metal sleeve G, the end H of which is enlarged to fill the hole just above the seating. This enlarged head is milled on the edges into narrow channels, so that the oil is atomised as it is forced through these channels on its way to the cylinder. The more usual arrangement is to form the head of the sleeve with a series of washers drilled with holes about $\frac{1}{16}$in. diam., forming in this way passages offering high resistance to the flow of the oil. The va spindle B is lifted by the lever L against a strong spring; and the lever L is operated by the cam C, which is placed on the half-speed shaft. The lift of the spindle B is about $\frac{3}{32}$in.

A sketch of the oil pump is shown in Fig. 3. S is t suction valve; D_1, D_2 are two delivery valves in series; R the ram. The ram is driven by a small crank and connecti rod attached to the end of the half-speed cam shaft, as ind cated at C by dotted lines. A small screw-down valve V provided to test the oil flow; it opens communication into the space above the first delivery valve D_1, and when open, oil spurts from the pipe P when the pump is working properly. The quantity of oil forced through the delivery pipe during the down stroke of the ram R depends upon the fraction of the stroke of the ram at which the suction valve S closes; and this closing is determined by the action of the governor on the valve. Until the suction valve closes the ram merely dis-

* Paper read at the spring meetings of the fifty-fifth session of the Institution of Naval Architects, April 2nd, 1914.

places oil back through it into the supply chamber. The closing can be delayed by the action of the governor, so that in general part of the charge drawn in through the suction valve is turned back to the supply chamber Y through the suction valve, and the remainder is forced out through the delivery valves D_1, D_2 to the fuel valve in the cylinder cover of the engine, against the pressure of the air in the annular chamber surrounding the fuel valve. The proportion of the whole charge which is delivered through the delivery valves during the down stroke of the ram depends upon the position of the governor sleeve E. The mechanism by means of which the governor delays the closing of the suction valve is shown in the figure.

The link H is jointed at one end I to the link L, which hangs from the arm K. The arm K is connected to the governor sleeve, and pivots at N. The other end of the link H is connected to the crosshead pin Q, which drives the pump ram, so that as the engine works the link H executes angular oscillations about the joint I. The plug rod G is connected to the link H, so that it oscillates vertically through a range equal to about one-third of the stroke of the ram. The plug rod G passes

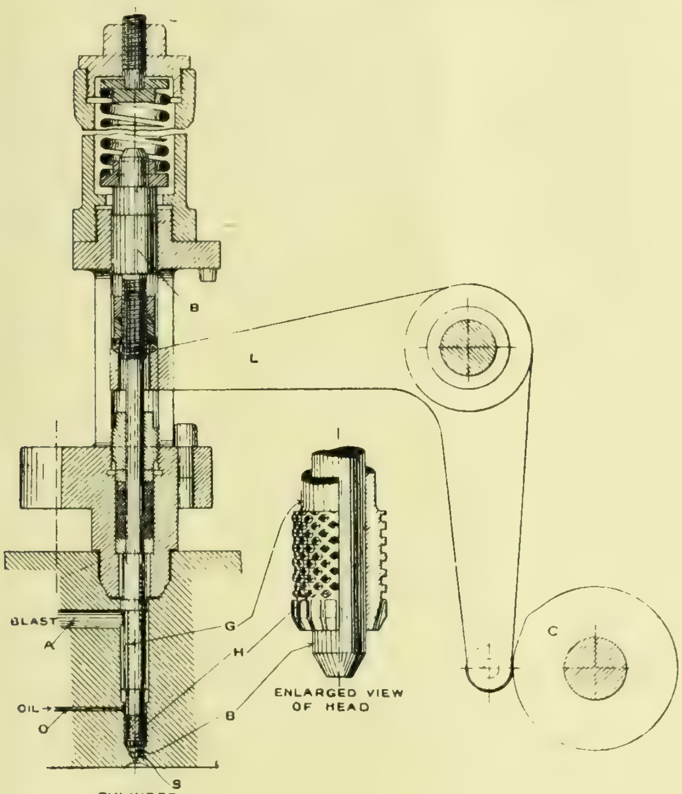


Fig. 2.

through the pump block B, which acts as a guide, and carries below an arm J fastened to it. Assuming that the governor is rotating steadily so that the pin joint I is at rest in the position corresponding to full load, the arm J, as it oscillates up and down, keeps clear of the end of the suction valve S. If the speed increases the pin joint I moves up as the governor sleeve moves up, and this movement brings the arm J into contact with the end of the suction valve during a portion of the stroke, and so delays its closing. From this it will be understood that the actual movement of the plug rod G is a resultant of two motions, namely, the motion of the joint I, produced by the movement of the governor sleeve, and the motion of the point Q, produced by the small crank on the end of the half-speed cam shaft.

The engine works on a modified four-stroke Otto cycle. Air is drawn in through the suction valve during the down stroke, and during the next upward stroke it is compressed to about 500lbs. per square inch. The temperature corresponding to this high pressure is sufficient to cause the oil to burn as it is sprayed into the cylinder. Just before the end of the compression stroke the fuel valve opens, and remains open during a fraction of the next down stroke. After the fuel valve closes and the burning is complete, the gas expands until the exhaust valve opens, and during the next up stroke the products of combustion leave the cylinder through the exhaust valve in the usual way. The cycle differs from the Otto cycle in that air is compressed instead of a

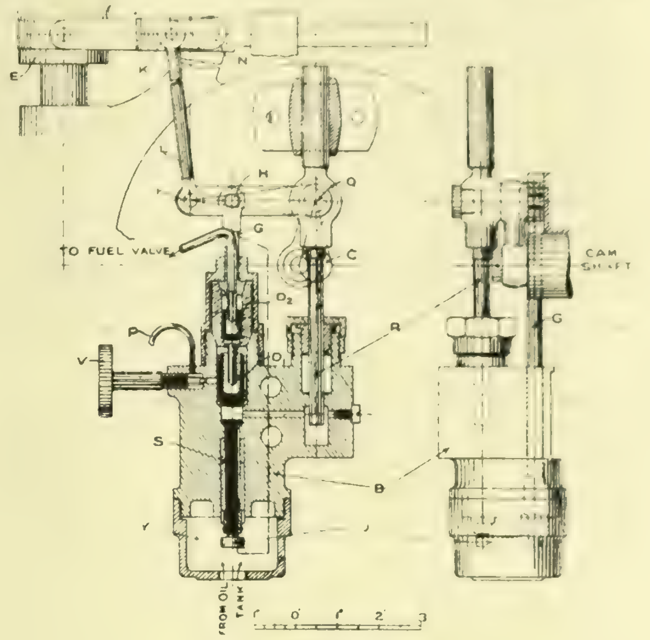


Fig. 3.

mixture of air and gas, and the gas burns at approximately constant pressure.

The cycle is illustrated by the indicator diagram (Fig. 4), which shows a diagram taken during a trial in which the engine developed 11·66 i.h.p. It shows clearly the high compression, the point at which the fuel valve opened, and the point at which it closed. The actual cut-off shown was somewhat later than the cut-off for which the cam was set, and this difference is produced by the inertia of the moving parts of the engine. It will be seen that the pressure at the end of compression is nearly 500lbs. per square inch, and that after the burning period the pressure falls by expansion to 25lbs. per square inch. The blast pressure is marked on the diagram together with the maximum pressure, from which it will be seen that there is a drop from 700lbs. per square inch to 529lbs. per square inch, that is, 171lbs. per square inch, through the nose of the fuel valve. The energy corresponding to this drop is used to atomise the oil. The mean pressure is 102lbs. per square inch.

It will be convenient here to briefly explain the general nature of the indicator with which this and the other diagrams in the paper have been taken. This indicator is an optical photographic apparatus. No piston or spring is used, and the variation of pressure in the cylinder is measured by the

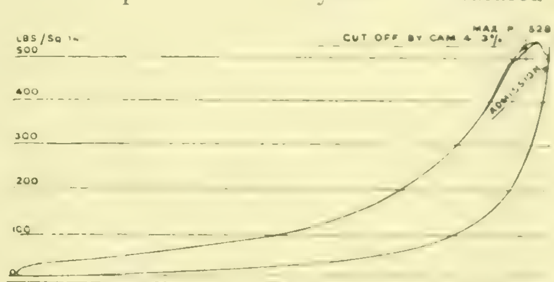


Fig. 4.

R.P.M. 256; I.H.P. 11·66; mean pressure 102·0lbs. per square inch; blast 700lbs. per square inch.

deflections of what may be called a thick telephone disc, which is connected by light mechanism with a small mirror, so that the deflection of the disc causes a corresponding angular tilting of the mirror. The range of action of the disc is only a few hundredths of an inch, and it will be understood, therefore, that for all practical purposes inertia is eliminated so far as the measurement of pressure is concerned. A second mirror, whose axis is placed at right angles to the first mirror,

receives an angular motion proportional to the piston displacement. A beam of light from a source within the apparatus falls upon each mirror in succession, and is brought to a focus on the ground-glass screen of the camera which is attached to the indicator. When desired the screen may be replaced by the photographic plate. Ordinarily, when the engine is running, the indicator diagram appears on the ground glass drawn out light, and every variation in the working of the engine can be watched. The second mirror, whose angular motion is proportional to the piston displacement, is not connected directly with the piston. Interposed between it and the piston mechanism is a phase changer, which is driven from the crank shaft by means of sprocket wheels and a pitch chain. The shaft of the phase changer carries a small crank, and a rod connects it with the arm of the mirror. The ratio between this small crank and the connecting rod is the same

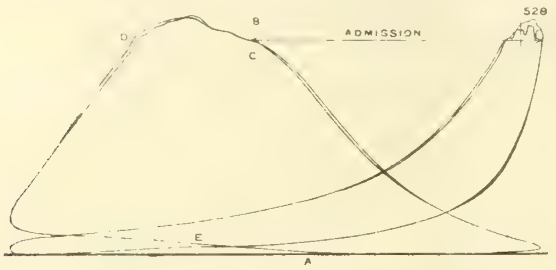


FIG. 5.

R.P.M. 256; I.H.P. 11·66; mean pressure 102·6lbs. per square inch; blast 700lbs. per square inch.

as that between the actual crank and connecting rod in the engine.

This arrangement enables the phase of the diagram to be changed quickly through any number of degrees while the engine is running. It is particularly interesting to change the phase through 90°. When this is done the dead point period is exhibited on an approximate time base instead of on a piston displacement base, so that the variation of pressure in the dead-point region can be more easily studied. I may add that after each diagram is taken it is in general calibrated *in situ*. The diagram shown in Fig. 4 was calibrated *in situ*, and the scale of this was used for all the others, because, after taking a large number of diagrams, it was found that the scale did not alter.

Fig. 5 is another diagram taken during the same trial, showing in addition to the normal diagram a second diagram altered in phase through 90°. The compression curve now

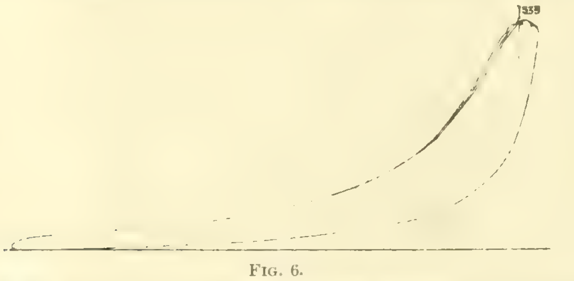


FIG. 6.

R.P.M. 259; I.H.P. 10·7; mean pressure 92·5lbs. per square inch; blast 675lbs. per square inch.

begins at A, and, going to the right, ends at B. The fuel valve was opened at the point C, a point well marked on the diagram. The subsequent changes in pressure during the burning period are clearly shown. The expansion curve begins at D, and continues until the exhaust valve opens somewhere about the point E. The diagram can be altered through 90° in this way in a few seconds; in fact, without taking one's eyes from the focussing screen on which the diagram is being produced. Fig. 6 shows a diagram taken at 10 h.p., giving a mean pressure of 92·5lbs. per square inch. Fig. 7 shows a diagram at 7·27 h.p., with the governor acting to regulate the oil supply. The regulation is clearly shown both by the normal diagram and the second diagram changed in phase through 90°. Fig. 8 was taken at no load, and in this case the drop of the pressure line is emphasized still further. In each of these diagrams the blast pressure is marked above the maximum pressure.

Fig. 9 shows a diagram taken at 12·6 h.p. In this case the mean pressure was 118lbs. per square inch and the blast pressure 715lbs. per square inch, dropping to a maximum pressure of about 558lbs. per square inch in the cylinder. The corresponding diagram is also shown changed in phase through

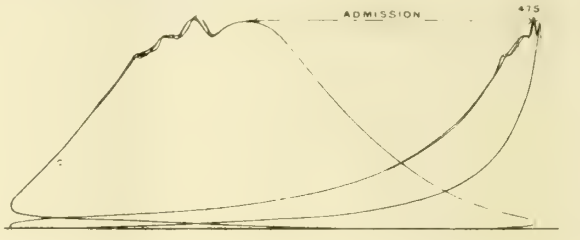


FIG. 7.

R.P.M. 264; I.H.P. 7·27; mean pressure 61·6lbs. per square inch; blast 575lbs. per square inch.

90°. In this case compression ends at C, and the phase is changed so that the compression curve is on the left of the diagram. Fig. 10 shows four diagrams superposed, so that a general view of the whole set can be obtained. The cut-off was the same in each case, being fixed by the cam. It will be seen that the compression curve is practically coincident for each diagram, and that burning takes place at a slightly rising pressure during the full load diagram, and as the load is decreased the burning pressure gradually decreases; in fact, at no load the pressure line almost merges into the expansion line.

Trials.—The following are the main dimensions of the engine: Cylinder, 6·5in. diam.; stroke, 10$\frac{5}{8}$in.; connecting rod, 28in.; air pump pistons, 3$\frac{7}{8}$in. and 1$\frac{3}{16}$in., with a common stroke of 2$\frac{3}{4}$in.; diameter of flywheel, 5·34ft.; rim, 6in. wide;



FIG. 8.

R.P.M. 270; I.H.P. 4·5; mean pressure 37·9lbs. per square inch; blast 190lbs. per square inch; no load.

compression ratio, 14·3. The cams on the crank shaft are set so that the air inlet valve opens when the crank is 20° before its dead point position, and it closes when the crank is turned through 195° from its dead point position. The fuel valve is set to open when the crank is 6° before its dead point position, and closes when the crank is turned 24° after the dead point position. The exhaust valve opens when the crank is 45° from its dead point position, and closes when the crank has passed 4° beyond the upper dead point position. It will thus be seen that through 24° movement of the crank the air inlet valve and the exhaust valve are open together

The fuel used during the trial was contained in a tank of about 12 gallons capacity, placed 6ft. above the centre line of

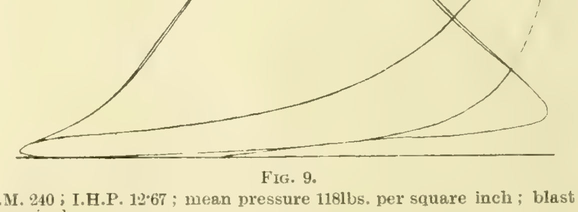


FIG. 9.

R.P.M. 240; I.H.P. 12·67; mean pressure 118lbs. per square inch; blast 715lbs. per square inch.

the cylinder, as illustrated in the diagram (Fig. 1). By the side of this tank is a smaller tank of about 2 litres capacity, fitted with a hook gauge. Before making a trial, the smaller tank is filled up to the hook gauge, and then, by means of a three-way valve, it is shut off, and the fuel is supplied to

the engine from the main tank. This may be called the normal condition of running. The trial begins when the three-way valve is thrown over, and the supply of oil is drawn from the smaller tank. The trial ends when the valve is thrown over to the normal direction of running, and the engine is again drawing its supply from the main tank. Oil is then weighed into the smaller tank until it is filled to the lever of the hook gauge. In this way an accurate measurement can be made of the oil

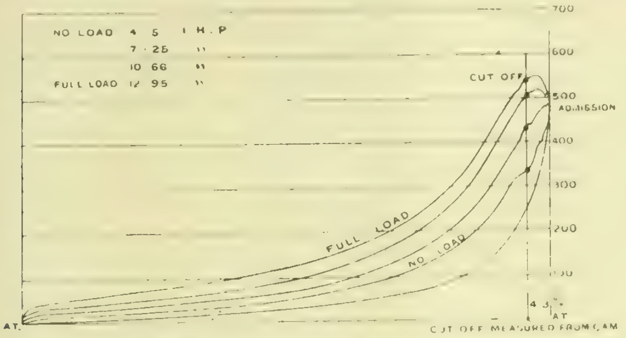


FIG. 10.—SUPERPOSED DIAGRAMS TAKEN WITH OPTICAL INDICATOR. Cylinder 6·5in. diam., 10⅝in. stroke, compression ratio 14·3.

used by the engine during an observed interval of time without in any way disturbing the conditions of running. The oil used in these trials was a heavy Russian oil. Its calorific value, measured with a Junker calorimeter, was 9,340 calories per pound. Its specific gravity was ·812.

The accompanying table shows the results of the trials. *Line* 2.—The indicated horse-power was measured with the optical indicator. *Line* 3.—The brake horse-power was measured by an ordinary rope brake. *Line* 5.—The oil measurement was made in the way described above by means

passing through the orifice. The flow for the orifice used is given by—

$$W = 9{\cdot}45\sqrt{H}$$

where W = pounds of water per minute flowing through the orifice,

and H = the head of water over the orifice, in feet.

The measure was correct within ½ per cent.

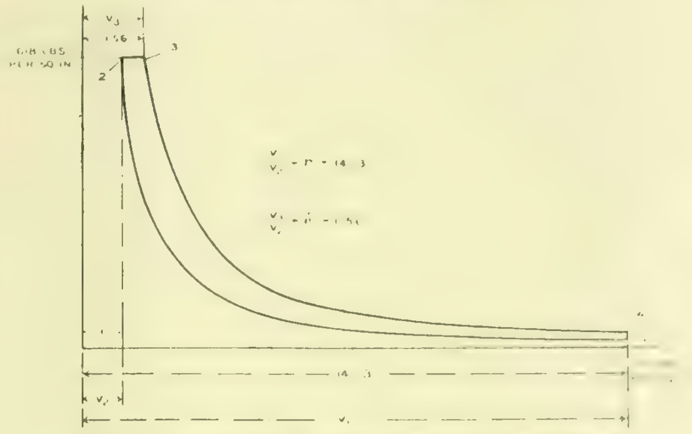


FIG. 11.—P.V. DIAGRAM FOR IDEAL ENGINE OF COMPARISON.

As shown on the diagram (Fig. 1), there are four independent water circulations in the plant: an independent circulation through the main cylinder jacket, through the cooler, through the low-pressure compressor jacket, and through the high-pressure compressor jacket. All of these circulations were measured together as indicated. The bulk of the flow was through the main cylinder jackets, quite small quantities flowing in the other circulations. The temperature measured was the common temperature of the whole discharge.

Summary of Trials of 10 h.p. Diesel Engine.

Line No.		No Load.	½ Full.	¾ Full.	·83 Full.	Full.
1	Duration of trial ...	60 min.	60 min	60 min.	60 min.	60 min.
2	I.H.P. ...	4·5	7·27	10·66	11 69	12·95
3	B.H.P. ...	0·0	3·33	6·71	8·35	9·94
4	Mechanical efficiency ...	—	45·8 %	63 %	71·4 %	76·75 %
5	Oil supplied to engine during the trial ...	1·5 lbs.	2·372 lbs.	3·63 lbs.	4·35 lbs.	5·44 lbs.
6	Oil per I.H.P. hour ...	·333 ,,	·326 ,,	·340 ,,	·372 ,,	42 ,,
7	Oil per B.H.P. hour ...	—	·713 ,,	·541 ,,	·521 ,,	·548 ,,
8	Mean revolutions per minute ...	·270	264	2[illegible]9	256	250
9	Mean effective pressure, lbs. per sq. inch ...	37·6	61·6	92·1	102 9	117 7
10	Cut-off determined by cam, per cent. of stroke ...	4·23	4·23	4·23	4·23	4 23
11	Pressure in storage bottle, by gauge ...	875 to 1,060	1,080 to 1,070	1,075 to 1,095	1,100 to 1,110	1,112
12	Pressure in inter-cooler, by gauge ...	110 to 115	120 to 118	117	115	115
13	Maxm. pressure in cylinder, measured from indicator diagram	469 lbs. sq. in.	478 lbs. sq. in.	535 lbs. sq. in.	529 lbs. sq. in	531 lbs. sq. in
14	Blast pressure, by gauge... ...	483 ,,	575 ,,	675 ,,	700 ,,	715 ,,
15	Drop of pressure through fuel valve ...	14	97	140	171	184
16	Cooling water flowing through plant, lbs. per min. ...	10	11·35	11 47	11 15	11 67
17	Rise in temperature, degrees Centigrade ...	7·1	8 5	11 4	12 8	16 2
18	Heat carried away by cooling water, lb. cals. per min....	71	96	131	142	189
19	Heat produced by the combustion of the fuel, lb. cals. per min.	234	369	565	677	847
20	Heat equivalent to I.H.P. ...	106	171	251	275	30[illegible]
21	Thermal efficiency, reckoned from I.H.P. ...	45·3 %	46 4 %	44·4 %	40 6 %	36 %
22	Heat equivalent to B.H.P., lb. cals. per min. ...	—	78	158	197	234
23	Thermal efficiency, reckoned from B.H.P. ...	—	21·1 %	28 %	29 %	27 7 %
24	Heat equivalent to I.H.P., per cent. of heat supplied...	45	46	44	41	36
25	Heat carried away by cooling water, per cent. of heat supplied	31	26	23	21	22
26	Heat carried away by exhaust gas, radiation, &c., by difference	24	28	33	38	42
		100	100	100	100	100
27	Efficiency of standard engine of comparison ...	·62	·62	·62	·62	62
28	Relative efficiency, reckoned from the I.H.P....	·73	·75	·72	·65	·58
29	Relative efficiency, reckoned from the B.H.P....	—	·34	·45	47	44

CALORIFIC VALUE (LOWER) OF THE OIL, 9,340LB. CALORIES. SPECIFIC GRAVITY, 0·812.

of a small tank connected to the main tank and to the engine through a three-way cock. *Line* 16.—The cooling water flowing through the plant was measured by means of an orifice tank designed by the author, in which, instead of the turbulence of the water being baffled out by means of wire gauze and perforated zinc plates, the stream lines are brought to a parallel direction by a properly shaped deflecting piece before

The thermal efficiency of the engine is shown in line 21 of the table. In line 23 the thermal efficiency is calculated with reference to the brake horse-power. The heat lost by radiation and in the exhaust is found by difference and is recorded in line 26 as a percentage. The distribution of heat through the engine is shown in lines 24, 25, and 26.

Line 27.—The standard cycle with which the performance

of a Diesel engine is usually compared is one in which heat is received at constant pressure and rejected at constant volume, and using air as the working agent. Also, the ideal engine works with the same cut-off as the actual engine. A sketch of the ideal diagram is shown in Fig. 11. Both the compression curves and the expansion curves are in this diagram adiabatic, following the relation $P V^{1.4}$ = a constant. Neglecting the variation in the specific heat of air, and indicating

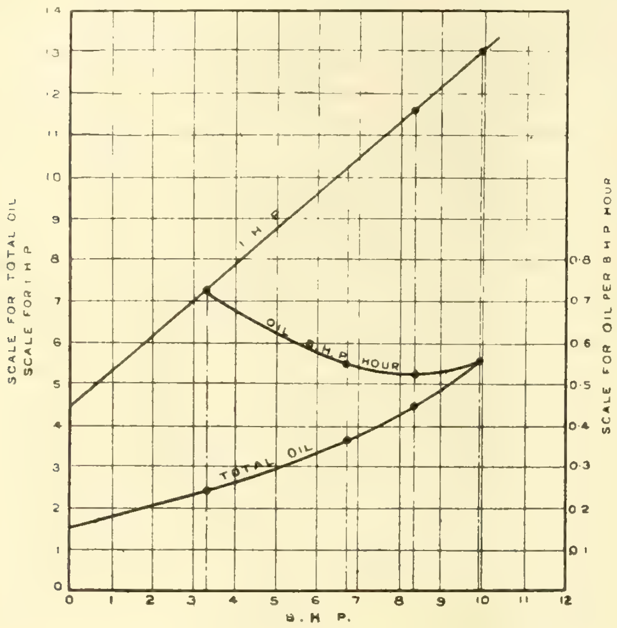


Fig. 12.

by subscripts 1, 2, 3, 4, the state as regards either temperature, pressure, or volume at the correspondingly numbered points of the diagram, the heat received per cycle is—

$$K (T_3 - T_2)$$

and the heat rejected per cycle is—

$$K_v (T_4 - T_1).$$

Hence the efficiency of the ideal engine is—

$$\eta = \frac{K_p (T_3 - T_2) - K_v (T_4 - T_1)}{K (T_3 - T_2)}.$$

Let δ be the ratio,

$$\frac{\text{Volume at cut-off}}{\text{Volume of clearance}} = \frac{V_3}{V_2}.$$

And let r be the ratio,

$$\frac{\text{Maximum volume}}{\text{Clearance volume}} = \frac{V_1}{V_2}.$$

And γ the ratio

$$\frac{K_p}{K_v} = 1{\cdot}4.$$

Then it is easily shown that—

$$\eta = 1 - \frac{1}{r^{(\gamma-1)}}\left(\frac{\delta^{\gamma} - 1}{\gamma(\delta - 1)}\right) \quad . \quad . \quad . \quad (1)$$

The measured value of δ for the setting used in these trials was 1·56, and the measured value of r was 14·3. With these values the efficiency of the engine of comparison is 0·62. It will be seen that this small engine in a trial at one-third full load realised 75 per cent. of this value, and in the 0·83 full load trial it realised 65 per cent. of this value. This expression for the efficiency of the ideal engine is similar in form to the expression for the efficiency of the constant volume cycle, namely—

$$\eta = 1 - \frac{1}{r^{(\gamma-1)}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Expression (1) is, in fact, obtained from expression (2), if the second term of (2) is multiplied by the factor

$$\frac{\delta^{(\gamma-1)}}{\gamma(\delta - 1)},$$

a factor which depends upon the cut-off. This factor is greater than unity, and hence the second term of (1) is greater than the second term of (2), and the efficiency represented by (1) is less than the efficiency represented by (2) for corresponding conditions. Comparing two engines having the same compression ratio, one working on the constant-volume cycle and the second working on the constant-pressure constant-volume cycle, it will be seen that the constant-volume cycle is more efficient, and that the constant-pressure cycle approaches this efficiency as the cut-off factor is reduced. Hence the earlier

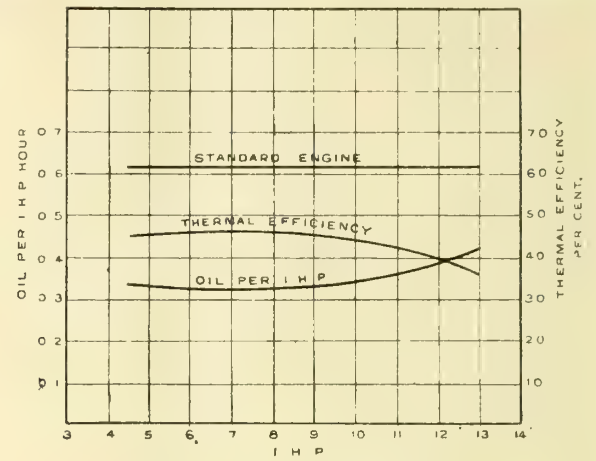


Fig. 13.

the cut-off, the more economical the Diesel engine is likely to be. It is also evident that this is likely to be the case from the consideration that the earlier the cut-off the lower the temperature to which the products are reduced at the end of expansion, and the smaller, therefore, the quantity of heat rejected.

The results of the experiments are plotted in Fig. 12 against the b.h.p. It will be seen that the i.h.p. line is almost straight, and that the oil per brake horse-power hour is a minimum at about 8 h.p. The results are plotted against the indicated horse-power in Fig. 13. These curves show that the thermal efficiency is a maximum at about 7 h.p. The two diagrams, viz., Figs. 12 and 13, together with the indicator diagrams, exhibit the working of a Diesel engine through its whole range of economical action.

TURBO-COMPRESSOR AND TURBINE.

The accompanying illustrations show a machine designed and patented by Mr. M. H. Churchill-Shann, No. 23, Priory Park Road, Kilburn, London, which may be utilised either as a compressor or turbine. It comprises an annular low-pressure and an annular high-pressure chamber respectively. The turbine nozzles revolve in close contiguity to the pressure chamber, having an annular converging lip, the end of which is formed by the revolving nozzles. Consequently there is an unrestricted flow through the nozzles from the annular lip. The high-pressure orifices are arranged for axial flow with a directional inclination, so that the centrifugal force acts in favour of the difference of pressure. The high-pressure orifices are very small relatively to the low-pressure orifices, and the high-pressure orifices are pitched relatively far apart, whereas the low-pressure orifices are as nearly contiguous as the constructional requirements will allow of. An annular lip is provided on the high-pressure chamber with a diminishing area as it approaches the revolving nozzles. The low-pressure orifices of the nozzles abut against a ring of fixed reaction blades. These blades have their high-pressure side provided with orifices practically directly parallel to the axis, and on the low-pressure side the orifices have a directional inclination. A set of moving blades is fitted on the low-pressure side of the fixed reaction blades, these moving blades being so shaped that their high-pressure side has a direction practically at right angles to the direction of rotation, whereas their low-pressure side has a directional inclination of about 30° to the direction of rotation. This arrangement ensures that the space between the blades, measured on the shortest distance between them, is on the low-pressure side about half of that on the high-pressure side. In order to compensate for this difference the radial dimensions of the blades are made nearly

twice as great on the low-pressure side as the dimensions on the high-pressure side. The blades are shrouded at the top and the bottom, and the flare of the shrouding on the moving blades is made much more on the bottom or small radius than on the top or larger radius, so as to compensate as far as possible for the centrifugal force. The fixed reaction blades have a greater flare on the top or outer radius than on the bottom, so as to keep the centre line of action parallel to the

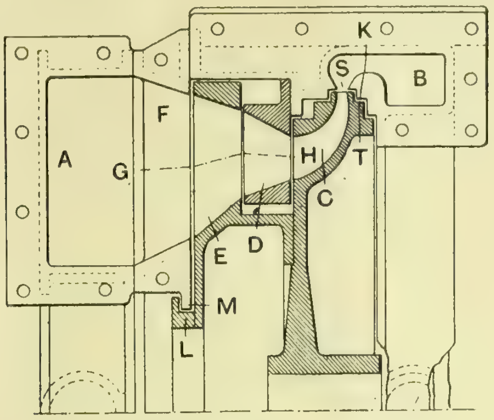


Fig. 1.

axis of rotation. The fixed reaction blades as well as the moving blades are gradually thickened from the low-pressure side to about two-thirds of the axial width, and are then tapered down to the same thickness on the high-pressure side as that on the low-pressure side. This construction ensures that although the profile of the flare on the moving blades coincides with that on the fixed reaction blades which abut on the moving blades, the area of the passage through the fixed reaction blades abutting on to the moving blades is much smaller than the area of the passage through the moving blades abutting on the fixed reaction blades. This sudden alteration of area decreases the resistance to flow at the point where the resistance is most felt on passing from one set of blades to another. The same effect is also secured at the junction between the nozzles and the fixed reaction blades. In both cases, the object is to ensure a sudden enlargement of area at the low-pressure side of the junction of the moving and fixed blades.

When the apparatus is used as a turbine the steam is supplied to the annular high-pressure chamber in a tangential direction. The object of this in combination with the rotating

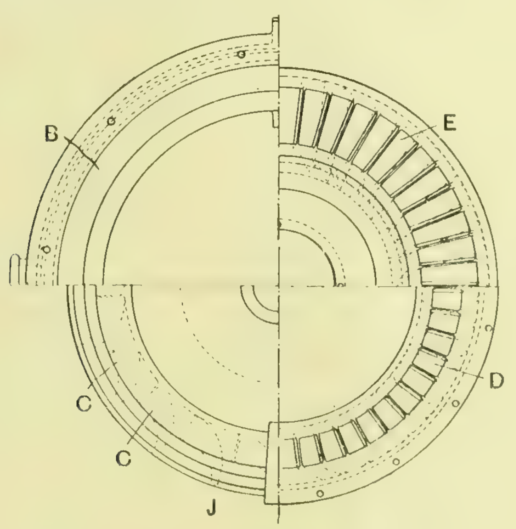


Fig. 2.

nozzles is to provide an apparatus in which, as the speed of rotation increases, the supply of working fluid to the nozzles is materially diminished, so as to prevent too great a speed. The operation of the machine is similar to that of other turbo-generators of this class. The steam entering through the gas inlet into the annular high-pressure chamber escapes through the high-pressure nozzles into the low-pressure chamber, and then flows out through the low-pressure nozzles, encountering the fixed baffles in its passage to the outer atmosphere. When the apparatus is used as a compressor its operations are reversed, and the outer air or other source supplies the elastic fluid, which is first compressed in the low pressure rotary apparatus and is then raised to its full compression in the high-pressure apparatus in the usual manner.

Fig. 1 is a plan view in part section showing, however, only one-half of the apparatus. A is the low-pressure annular chamber, B the high-pressure annular chamber, C the revolving nozzles, D the fixed reaction blades, E the revolving blades, and F the radial fixed blades. Fig. 2 shows views in an axial direction. B is the high pressure chamber viewed from the low-pressure chamber A, C the corresponding view of the revolving nozzles regarded from the reverse direction, J the radial orifices, D the corresponding view of the fixed reaction blades looking towards A, and E the corresponding view of the moving blades looking from B towards A. All these views only show one quarter of the complete set. Fig. 3 shows a diagrammatic development in the direction of rotation of F, E, D, and C relatively to one another. The fixed portions A, B, D, and F have flanges on each, so that they can be removed without disturbing the rotating portions. K, T are the stepped portions of B and C, to ensure that the working fluid does not leak out of B. L, M are the corresponding seal on the low-pressure end of the revolving parts. G H is the centre line of the blading. This centre line has an important bearing on the design, and is the result of the flare not being symmetrical on the inner and outer radii on the fixed and moving blades. This gives the result that whilst the average radial length remains nearly constant, there is a greater mean radius on the high-pressure side of the moving blades than on the low-pressure side, and a smaller mean radius on the high-pressure side of the fixed blades than on the low-pressure side. When the apparatus is used as a compressor this ensures that the centrifugal force will assist the action of the compressor; when used as a turbine the centrifugal force prevents too free a blow-through of the working fluid. S is the contracting lip on B where it approaches the high-pressure side of C so as to provide an easy path either to or from C and B, according as the apparatus is used as a compressor or as a turbine.

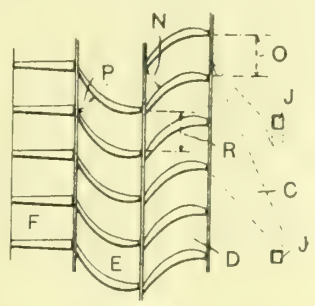


Fig. 3

Fig. 3 shows the kind of blading used in D and C; whereas the line N denotes the distance between any two blades measured normally at the low-pressure side of D, O denotes the distance between any two blades measured at the high-pressure side of D. Similarly P and R denote the distances between any two blades in E, measured normally on the low and high-pressure sides. In the case shown N is less than O and P than R. But this alteration is mainly from the mid-section to O and R, that is, the distance between any two blades increases more rapidly as the pressure side is approached. The flare of the shrouding of both D and E as shown provides that the area of the space between any two blades is about equal on the low and high pressure sides. This equality is not the essential point, however, but rather that the area shall increase from mid-section towards the high pressure side, in order to facilitate the passage of the fluid from one set of blades to another.

West of Scotland Iron and Steel Institute.—The monthly meeting of this Institute was held in Glasgow on the 20th ult. Two papers were read and illustrated by lantern views. The first was on "The Influence of Manganese in the Corrosion of Steel," by Dr. C. H. Desch and Mr. S. Whyte. The result of their research, although not conclusive, favoured the opinion that manganese in itself was rather protective than otherwise, and that the disfavour with which it used to be regarded was due to its action when associated with sulphur. Mr. N. K. Turnbull, Manchester, gave an interesting résumé of the work of "Hot Galvanising," which he illustrated with specimens and slides.

TESTING LUBRICANTS.

When purchasing a lubricant for any particular purpose the fact should not be lost sight of that it is not always the price of an oil that denotes its value. Every machinist knows that oil is cheaper than friction, but few appear to realise that a lubricant must be strictly adapted to the work it has to perform, or to know that a low-priced oil may better satisfy some of their requirements than would an oil of a higher price.

Comparatively recently coal consumers began to recognise that the true value of a fuel lay in the amount of heat that could be got out of it, and now all coal contracts of any magnitude are based on the calorific value of the fuel as determined by its combustion in a bomb calorimeter. And that being for all practical purposes the only factor the coal consumer need take into consideration, the problem of selecting his fuel is not difficult of solution.

For the oil user, however, the task of correctly specifying the proper lubricant for his purpose is far from being an easy one, for many varying factors enter into the problem, even when dealing with lubricants for the same type of machinery. Thus, an oil that would be quite suitable for use in a cylinder working with saturated steam would give poor results in the same cylinder if superheated steam were used, and would be entirely out of place in the cylinder of an internal-combustion engine. And so, like the coal consumer, the oil user relies upon mechanical means for the solution of his problem, and finds that the only reliable way to ascertain the true lubricating value of an oil, or grease, is to test it in an apparatus specially designed for the purpose.

It is claimed for the Sternol Oil Testing Machine that by its aid the oil user can not only have the correlation that should exist between the machinery to be lubricated and the lubricating medium it is proposed to employ for the purpose accurately determined, but also automatically recorded for future reference. The machine is a complete self-contained oil and grease testing plant, including a small high-pressure steam boiler and superheater, and is so arranged that all tests made by it are carried out under conditions which are in every respect the exact mechanical counterparts of the work to be done by the lubricant. And to accomplish this the speed of the machine can be varied from 50 to 3,000 revs. per minute, corresponding to a speed of the frictional surfaces of about 5in. to 25ft. per second, and the pressure increased from 1lb. to 750lbs. per square inch. The temperature can be adjusted from that of the frictional surfaces when at rest to 500° C., which is considerably in excess of the heat of dry steam produced under the highest pressure. By means of the steam boiler and superheater every variety of cylinder oil can also be tested under actual working conditions for saturated or superheated steam, the disintegration of the oil, if any, and the amount of sediment formed being noted by flowing the oil upon test paper. Perhaps the most interesting part of the machine is the recording mechanism, which indicates automatically and on the same sheet of paper every stage of each test, and thus the degree of friction and the temperature of the frictional surfaces are recorded for any lubricant; the curves being such that they also indicate the proportional thickness of the layer of oil required to maintain efficient lubrication at the given temperature, together with the comparative values of the oils in relation to their capacities for withstanding different temperatures.

The machine is manufactured by the Stern Sonneborn Oil Company, Ltd., of Finsbury Square, London, E.C., and we understand that they will test any sample of oil, or grease, submitted to them, and, with such data available, the oil buyer should have little difficulty in selecting with certainty the cheapest quality of lubricant capable of yielding the highest degree of efficiency for his particular purpose.

Proposed Abolition of External Degrees in Engineering.—At the last meeting of the Council of the Society of Engineers the following resolution was passed: "That the Council of the Society of Engineers (Incorporated) are of opinion that the abolition of the external degrees in engineering proposed by the Royal Commission on University Education in London would be a grave injustice to many engineering students, and they are strongly opposed to the recommendation being carried into effect."

FACTOR OF SAFETY.

In the course of a paper on this subject read by Mr. C. E. Stromeyer, before the Staffordshire Iron and Steel Institute, on March 28th, the author said that the term "factor of safety" covered our ignorance of the real properties of materials and their behaviour when stressed. Much had been done in the past by the introduction of quality tests and the use of testing machines, but much yet remained to be done before even engineers could take the initial step of defining how many chances there were for and against occasional failures. Let it be assumed that a piece of steel were placed before us of which the average test results showed that it broke down at 15 tons. Assume also that there was a chance that the chemical composition was not quite what it should be, that the casting temperature and subsequent heatings might have affected the grain, and that initial strains had not been entirely removed, &c. Separate these various possibilities into, say, 10 influences, of which each one would affect the elastic limit by $\pm$ 1 ton, then there were $2^{10}=1{,}024$ possible combinations, and the chance that all the five adverse circumstances would combine together and result in a low breakdown point of $15-5=10$ tons per square inch was one in 1,024. There was also this one chance that the breakdown point would be $15+5=20$ tons. Against this there were 252 chances that its value would be equal to the average of 15 tons,and 672 chances, or 67 per cent., that the breakdown point would be between 14 and 16 tons per square inch, &c. Suppose now that nine tests had been made of this material, then the results would very likely be as follows: One of 13 tons, two of 14 tons, three of 15 tons, two of 16 tons, and one of 17 tons. Most engineers would accept the average result of 15 tons and apply a factor of safety without looking into the distribution of the test results, but the more correct procedure would be to say: These nine tests indicate that if we were to make 1,024 tests, one of these would give a limit of only 10 tons per square inch, and in order to be safe we must not depend on a higher value. If with another lot of steel, the test results should be as follows: One of 14, two of 14½, three of 15, two of 15½, and one of 16, then the conclusion to be drawn would be that there was a chance of one failure occurring at 12½ tons. On the other hand, if the test results were to be more scattered, say one test of 11 tons, two of 13, three of 15, two of 17, and one of 19, the conclusion should be drawn that one failure per thousand tests was likely to occur at 5 tons per square inch, and this should be the permissible maximum stress. It would thus be seen that the habit of engineers to accept average results might with advantage be replaced by the one adopted by astronomers, chemists, and others who, when stating average results, also added a $\pm$ quantity which indicated the probable average error. To be of value in this respect laboratory test results should indicate not the probable mean error, but the maximum one, which was, of course, outside the limits of the extremest tests. Then, however, much of our uncertainty would be removed, and the factor of safety might be correspondingly reduced.

The Work of Dr. H. C. Sorby.—At a recent meeting of the Sheffield Society of Engineers and Metallurgists, Prof. W. G. Fearnsides, the first holder of the Sorby Professorship of Geology at Sheffield University, delivered the first Sorby lecture, and confined himself to the work of Dr. Sorby, whom he described as the father of modern petrography and of metallography, in so far as it dealt with igneous rocks and metals, and pointed out that Sorby, in 1849, prepared the first rock slice ever made. He began his work on metals in 1863, but for 22 years his observations attracted no attention, and when in 1887 Prof. Martens in Berlin, and later M. Osmond and M. le Chatellier in Paris, began to study metals with a microscope, they had to develop independently and anew the craft which Sorby had invented many years before. It was in 1885, by the use of lenses of high resolving power and great magnification, that he first saw the true nature of the "pearly constituent" of steel as an aggregate of parallel plates, which discovery, being the earliest recognition of the crystallisation of a solid solution, might be reckoned the crowning achievement of his microscopical research.

CURRENT-LIMITING REACTANCES ON LARGE POWER SYSTEMS.*

BY K. M. FAYE-HANSEN AND J. S. PECK.

ONE of the most striking developments in connection with the supply of electrical energy is the rapid rate at which generating stations and generating units are increasing in size. This increase is due not only to the more general use of electricity for lighting and for domestic purposes, but to the fact that large manufacturing firms, tramways, railways, and other large employers of labour, are finding it cheaper to purchase electrical energy than to generate it in their own power stations. Thus an ever-increasing proportion of the community is becoming dependent upon the continuity of supply from these stations, and the time is fast approaching when a serious disaster to a large supply station may pass from a mere inconvenience to a civic calamity. On account of their size, however, these large stations have a power of causing internal and external damage quite beyond that possessed by a station of small or moderate size; it is therefore incumbent upon their designers not only to use every means to prevent accidents, but to make such provision that, if accidents do occur, the amount of damage shall be reduced to a minimum and the trouble confined to the particular section of the plant where it occurs. To accomplish these results current-limiting reactances are being extensively adopted.

The general effect produced by a series-reactance is a drop in voltage in the circuit, provided the power factor is unity or lagging; and the greater the lag the greater is the drop in voltage. The power factor is also decreased on account of the reactive kilovolt-amperes of the choke coil. It may be stated that the number of kilovolt-amperes at zero power factor is increased by the kilovolt-amperes of the reactance coil. This is but another way of saying that the wattless kilovolt-amperes of the choke coil may be added arithmetically to the other wattless kilovolt-ampere components of the circuit in order to give the total wattless kilovolt-amperes. Thus it is evident that the introduction of reactance affects the regulation and power factor of the system; and these are two of the factors which determine the sizes that should be placed in generator leads or feeders.

In general, reactance coils may be placed in any one or more of the following positions: (1) In the generator leads; (2) in the feeders; (3) between sections of the busbars. In the various positions their effect upon the following should be considered: (*a*) Generators; (*b*) circuit-breakers; (*c*) voltage of supply; (*d*) continuity of service. The different conditions of operation to be considered are: (*a*) Normal operation; (*b*) short-circuit on feeder; (*c*) short-circuit on busbars; (*d*) short-circuit on generator.

The advantages of placing reactances in the generator leads only may be summarised as follows: (1) The busbar voltage may be kept constant, giving the same voltage on all feeders; (2) no damage to the generators in the case of a short-circuit on a feeder or busbar; (3) no damage to the generator circuit-breakers in any case; (4) synchronous apparatus will not fall out of step in the case of a short-circuit on the generator. And the disadvantages: (1) Enormous current-rush into a short-circuit on a feeder; (2) excessive load on the feeder circuit-breaker in the case of a fault on a feeder; (3) synchronous apparatus may fall out of step, and a complete shut-down may follow a short-circuit on a feeder or busbar.

Reactances in generator leads alone are of little value except for protecting generator windings and circuit-breakers, as they offer no guarantee of continuity of service except in the case of the breakdown of a generator. Their size will therefore be determined by the robustness of the generators and the circuit-breakers. Assuming that the average generator has a reactance of 6 per cent., and 6 per cent. is added in an external coil, the maximum current that can flow equals $8\frac{1}{3}$ times the normal current, or somewhat more than this due to the doubling effect. Any generator should be able to stand a current-rush of this magnitude. If the generator has 8 per cent. reactance, then 4 per cent. in the external coil will limit the current to the same value. Where a step-up transformer is connected between the generators and busbars it may be designed with high internal reactance, thus giving the effect of a reactance coil without any appreciable additional cost.

The advantages of reactance in the feeders are: (1) A short-circuit on a feeder causes no serious disturbance on the system, and there is no excessive overload on circuit-breakers or generators; (2) the feeder circuit-breakers may be of smaller breaking capacity than those where feeder reactances are not used; (3) the tendency of synchronous apparatus to feed back in the case of a busbar fault is slightly reduced by the feeder reactances. The disadvantages are: (1) The voltage drop on the feeders will vary with the load and cannot be compensated for by varying the busbar voltage; (2) a short-circuit on the busbar or generators is a short-circuit directly on the terminals of all generators. The generator windings and circuit-breakers may be damaged and the complete plant shut down; (3) a short-circuit on any generator or between any generator and its circuit-breaker may throw an excessive load on this circuit-breaker, and if it fails to clear the fault the whole system will be shut down.

The size of the feeder reactances will depend on the capacity of the feeder, as compared with that of the gene-

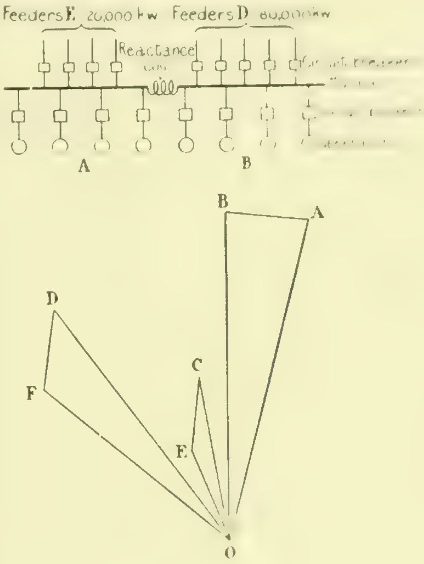


FIG. 1.

rators, and upon the breaking capacity of the feeder circuit-breaker. Thus if the rating of a feeder is one-quarter that of a generator, a reactance of 3 per cent. in the feeder will pass no more current than will a total reactance of 12 per cent. in the generator, while if there are several generators in parallel, the effect of the feeder reactances is proportionally increased. Thus unless the total feeder rating is very greatly in excess of that of the generators, the total kilovolt-ampere capacity of the feeder reactances may be less than the kilovolt-ampere capacity of the generator reactances, though the number will in general be much larger. In certain cases it may be desirable to group the feeders and use one set of reactances for the group, thus greatly reducing the number of reactances. If the feeders are of very great capacity compared with the generators, the feeder reactances must be much larger and their use may not be justified. Where step-up transformers form part of the feeders the transformers may be designed with high internal reactance without appreciable increase in cost.

The only purpose in installing busbar reactances is to limit the amount of current that can flow into a fault on one section of the busbars, and so to confine the disturbance to that part of the system on which the fault occurs. Viewed from this point only, the greater the reactance the better the result; in fact, the purpose would be accomplished perfectly by isolating the sections entirely. From economical considerations, however, it is highly desirable to operate all the generators of a station in parallel. As a compromise, reactances are chosen of such a value as to permit parallel operation during normal conditions, even with a considerable exchange of energy between the sections; while in the event of a short-circuit occurring on any section, the current-rush is

* Abstract of paper read before the Institution of Electrical Engineers.

limited to such a value as not seriously to interfere with the operation of other sections.

In order to obtain a concrete idea of the values involved in a specific case, an arrangement will be taken such as is shown in Fig. 1. Eight 10,000 kw. 10,000-volt generators are connected to the busbars, which are divided into two sections by reactance coils. Feeders D supply a load of 60,000 kw. at 0·8 power factor, and feeders E a load of 20,000 kw. at the same power factor. The voltages on D and E are to be kept equal, and all generators are to carry equal kilowatt loads. It is evident that one group of generators must supply 20,000 kw. to the busbars fed by the other group. Let the reactance coil be of such a size that with the current corresponding to 20,000 kw. flowing through it the voltage across it will be 25 per cent. of the normal. The capacity of this reactance = 5,000 k.v.a. 3-phase, or 1,660 k.v.a. for each phase. Draw O A and O B, making A B = 25 per cent. of O A. O D and O E represent the feeder currents laid off to the proper scale, each lagging approximately 37° behind its busbar voltage, O D being three times O E. D F and E C represent the currents through the reactance. O C is then the current supplied by generators A, and O F that supplied by generators B. Since with a current corresponding to the capacity of two generators the drop across the reactance is 25 per cent. of the normal, the maximum current that can

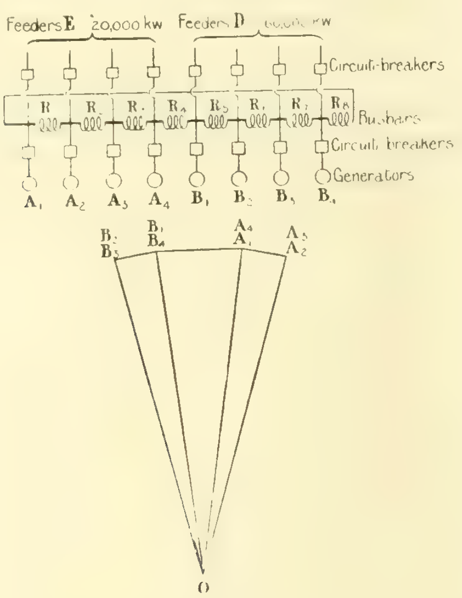


FIG. 2.

pass with full voltage across the coil is that corresponding to the normal current of eight generators, though this may be increased somewhat on account of the doubling effect.

This current is considerably less than a single generator can give at the instant of short-circuit, and is about the same as would be given by one generator after the time interval required for a circuit-breaker to open, so that the effect of the short-circuit would be no more severe than would be the case if there were a total of five generators coupled to one busbar. In a very large station the busbars would probably be separated into several groups of from 20,000 kw. to 40,000 kw. capacity each. In a case of this kind the amount of energy that it may be necessary to transfer between sections is assumed and the reactances made large enough to limit the current to a reasonable value in case of a short-circuit, but not too large for satisfactory parallel operation. A size that will give 50 per cent. of normal voltage with the full-load current of one busbar section is usually a reasonable value to choose.

The use of busbar reactances is carried to the extreme when the busbar is divided by them into as many sections as there are generators. Fig. 2 shows an arrangement of this kind where there are eight generators and eight reactances. It is assumed that each generator is of 10,000 kw. capacity, that the load on the D feeders is 60,000 kw., and that on the E feeders 20,000 kw. Then if all generators are to be equally loaded the A group must supply 20,000 kw. to the D feeders. Assume that all E feeders are equally loaded and that all the D feeders are equally loaded. Then through R_4 and R_8 must pass 10,000 kw., and through R_1, R_3, R_5, and R_7 5,000 kw. Since the busbar units are small, and it may be necessary to transfer energy through two or more reactances in series, they should be made smaller than where the busbar sections are larger in size but fewer in number.

Assume the voltage across reactances R_4 and R_8 to be 25 per cent. of the normal, corresponding to an angular displacement of voltage of approximately 15°. The voltage across reactance R_1, R_3, R_5, and R_7 will be 12·5 per cent., corresponding to an angular displacement of approximately $7\frac{1}{2}$°. Fig. 2 shows the voltage relations that exist between the different generators. It is improbable that the load on any busbar section will greatly exceed the capacity of the generator connected to that section, so that the conditions given above are as severe as are likely to be experienced in actual service; but even with a considerably more unequal distribution of load there should be no trouble in parallel operation. Arrangements will always be made for short-circuiting any reactance, so that in the event of a generator being shut down the feeders connected to its busbar section may be supplied directly from one of the adjacent generators. Arrangements must also be made for opening the busbars between any two generators in order to isolate any section of the busbars that might develop a fault.

With the arrangement shown in Fig. 2 assume that a short-circuit occurs on the busbar section supplied by B_4. The voltage on this generator would fall to zero, and it would supply maximum current into the fault. If the voltage on A_1 and B_3 kept up to normal for an instant, each of them would feed into the short-circuit four times normal current; but on account of the reactance in each armature circuit, which may be taken at, say, 5 per cent., the current would be $100/(25+5) = 3{\cdot}3$ times normal, and would drop quickly to a much lower value. The voltage at the same time would drop to perhaps 50 per cent. of the normal. As soon as the voltage on A_1 and B_3 begins to fall, generators A_2 and B_2 start to supply current through reactances R_1 and R_6. These currents would reduce to a slight extent the voltages on A_2 and B_2, but would tend to raise the voltages on A_1 and B_3. Similarly, A_3 and B_1 would tend to supply current through reactances R_2 and R_5 as soon as the voltages on A_2 and B_2 begin to fall. The effect, however, on the voltage of these generators would be practically negligible. To determine definitely the voltage on each generator and the current flowing through each reactance is a somewhat complicated problem, and requires definite data as to the characteristics of each generator, but sufficient has been said to indicate the general effect of the reactances in limiting the rush of current and the damage that can be done. Another advantage of using reactances between each generator is that it greatly reduces the chances of damaging a generator in the event of a mis-phase, a feature of considerable importance.

The advantages of busbar reactances are: (1) Trouble is confined to the particular section on which the fault occurs; (2) the amount of current that can be fed into a fault is reduced; (3) the danger in the case of bad synchronising is considerably reduced. And the disadvantages: (1) No protection to a generator is given when a short-circuit occurs on or near its busbar section; (2) the generators coupled to the different busbar sections must be operated with a certain angular displacement in their voltages.

Reactances between busbar sections may be exceedingly useful for confining any disturbance on the system to that particular section on which the trouble occurs, and thus it is possible to operate a large number of generators or two or more stations in parallel with almost the same factor of safety against a complete shut-down as though they were operated separately. It is seldom, however, that busbar reactances are used except in conjunction with reactances in generators or feeders, and it is proposed now to discuss very briefly their combined use.

Since the principal object of the generator reactances is to protect the generator windings, these will naturally be chosen with reference to the characteristics of the generator, and evidently one will be placed in each generator lead. The more completely the busbars are divided up by reactances the smaller will be the portion of the system affected, and from this point of view reactance is desirable between each

generator and the next; but as this may involve some slight complications in the normal operation of the plant, it may be considered desirable to operate with several generators connected to the same busbar section. The size of the reactances will be determined by the amount of energy that must be transferred from one section to another, and by considerations of successful parallel running. The advantage of this combination over the use of reactances in generators alone is very great, as it confines the trouble to the particular

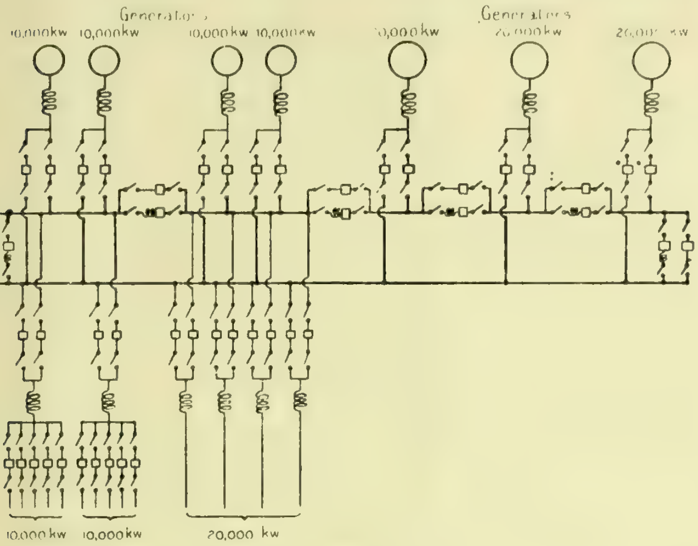


Fig. 3.

busbar section affected; it reduces the load on the feeder circuit-breaker, and reduces the damage at the fault. Perfectly satisfactory operation should be obtained with this arrangement.

Reactances will be placed in all feeders or alternatively in all feeder groups. Their size will be determined by the capacity of the feeder or group, with reference to the capacity of the busbar section and with reference to the breaking capacity of the circuit-breaker. This arrangement probably gives the greatest possible freedom from serious operating troubles, for the feeder reactances protect from all troubles outside the station, while the busbar reactances confine any internal trouble to the busbar section on which it occurs. The objections are that it affords no protection to the generators in case of a short-circuit on the busbars, that it requires a large number of reactance coils unless group feeding is adopted, and that it affects the regulation of the feeders, though this will ordinarily be of minor importance. If the generators can safely withstand a short-circuit, or if the chance of a short-circuit on the busbars is considered negligible, some form of this arrangement probably offers the most complete solution of the problem.

It has been attempted in the foregoing discussion to indicate the advantages and disadvantages resulting from the use of reactance coils placed in different positions in a power station, but when it is attempted to apply this knowledge to a concrete case there are so many factors to be considered that the determination of the best possible combination becomes a difficult problem. For example, if the busbars are divided into sections by reactance coils, and the different sections feed into the same busbars at one or more sub-stations, the impedance of the cables connecting the different sections may be far less than that of the reactance coils, so that much of the advantage gained by using the reactance coils is lost. Also there is the possibility that when one section is more heavily loaded than another, the cables on one section will be overloaded, due to the angular displacement in voltage between the sections. Thus it is desirable when using busbar reactances to feed one sub-station from one section of the busbars rather than from several sections, or, failing this, to use fairly large feeder reactances. When the feeders are very long this may not be of importance. When suitable feeder arrangements can be made, there seems no doubt as to the great desirability of using busbar reactances in large stations as an insurance against a complete shut-down. In the case of feeder reactances, the greatest flexibility is obtained by placing reactance in each feeder; this is quite feasible where the feeders are of large size and comparatively few in number, but where there are many feeders of small size the number of reactance coils becomes excessive and group feeding must be adopted.

Reactances in generator leads present the simplest problem, once it has been decided to install them. The only difficulty is to determine whether they are necessary in addition to the busbar reactances. The following points should be considered: If the generators will stand a short-circuit, reactances serve very little purpose except to protect the system in case of a generator breakdown and to reduce to a small extent the current that flows into a short-circuit. Busbars may be so thoroughly insulated as to reduce the possibility of a short-circuit to almost a negligible amount. It is now becoming fairly common practice to use single-core cable between the generators and busbars. These cables can be so arranged that an "earth" is almost certain to occur before a short-circuit, and a suitable discriminating device will cut off the generator and open its field circuit the instant that an "earth" occurs. Thus the chances of a short-circuit on the generator terminals may be greatly reduced. But there is still the possibility of a mis-phase where more than one generator is connected to the same busbar section; and if the generator will not withstand such an accident it will be advisable to use reactances in its leads.

In order to show a typical lay-out for a large station, the following conditions have been assumed: Total generator capacity, 100,000 kw.; seven generators (four of 10,000 kw. and three of 20,000 kw.); feeders of 2,000 kw. and 5,000 kw., the 2,000 kw. feeders being arranged in groups of 10,000 kw. each. A diagram of connections is shown in Fig. 3. In this case the busbars are divided into five sections of 20,000 kw. each. Each section of the busbar is fed either by one large generator or by two small ones. Between each busbar section is connected a reactance coil, which, with the full-load current of one busbar section, will give a voltage across it equal to 50 per cent. of the normal. Each reactance coil is arranged so that it may be short-circuited by means of an oil circuit-breaker, and an oil circuit-breaker is also placed between sections of the busbars. A ring busbar system is adopted, which increases considerably the flexibility of the arrangement. Each group of feeders will have in series with it a reactance coil, which should be of such a size that with the group fully loaded there will be a voltage across it of approximately 5 per cent. Each 5,000 kw. feeder should have in series with it a reactance coil, which will have a full-load voltage across it of approximately 2½ per cent. In series with each generator there should be a reactance of approximately 5 per cent. It is preferable to have each sub-station fed from one section of the busbars in order that circulating currents may not flow through the cables from one busbar section to another. The ring-main busbars and double set of feeder switches permit any sub-station to be switched over to another section in case of necessity. Discriminating devices should be provided so that in the event of an "earth" on any feeder it will be cut out. Also each generator should be arranged in a similar manner, so that it will be cut out in the case of an "earth" or other fault developing on it.

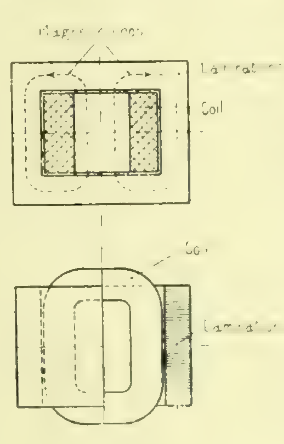


Fig. 4.

Current-limiting reactance coils have heretofore been designed almost exclusively without iron in the magnetic circuit. The larger coils have usually been cooled by means of an air blast. On account of the great shocks to which these coils are subjected it is necessary to adopt a very strong mechanical construction, and the winding must be so laminated as to reduce the eddy currents caused by the stray fields. The General Electric Company of America use a winding of stranded cable wound in concentric layers. The core is of concrete, and the different turns and layers of the

winding are spaced and held rigidly in position by spacing blocks of porcelain which are bolted together and to the core, thus making an extremely rigid construction. Each coil is usually placed in a cubicle made of bricks or tiles, which acts as a flue for guiding the air blast through the coil and prevents any person from coming in contact with the winding. On account of the heavy stray field outside the coil it is impossible to place it in a metal case, and it is advisable to keep it a considerable distance from any steel structure.

The American Westinghouse Company use a winding of stranded cable, but wind a number of pancake cores which are placed side by side. There is no central coil, and the turns and layers are held in position by means of fireproof partitions which are bolted together. This gives a very sound mechanical construction, and is easily adaptable for a wide range of capacities.

The air-core construction has been adopted upon the assumption that it would not be possible to use an iron circuit and obtain a straight line relation between the voltage and current without increasing the size, price, and losses in the coils. While this may be true for feeder reactances where the maximum short-circuit current is perhaps 20 to 30 times the normal current that the coils must carry without overheating, it is not true in the case of busbar reactances where the maximum current will, as a rule, not be more than four to ten times the normal current, and under certain circumstances the coil with a partial magnetic circuit will prove more economical than the air core even for generator reactances. The larger the capacity of a reactance coil and the lower the frequency, the less will be the advantage obtained by using iron in the magnetic circuit.

Fig. 4 shows diagrammatically the construction of a choke coil having a partial iron circuit. It will be noted that inside the coil there is no iron, and therefore the air gap is very large, while the coils are enclosed by a complete iron circuit. This construction has the following advantages compared with air choke coils: (1) Under normal working conditions there is no external field, so that the whole coil may be placed in a metal tank without fear of eddy currents, as though it were a transformer. (2) The coil may be operated in oil, thus avoiding the necessity for forced cooling, though the air-blast type can be used if preferred. (3) Less room in the station will be required, as it is possible to place the apparatus in the same position as a transformer and to handle it just as though it were a transformer. (4) The metal containing case may be earthed so that there can be no danger from accidental contact with the coil. (5) It is not essential to use a laminated cable winding, as the direction of the flux is such that a solid winding may be arranged by careful designing to avoid any serious loss. (6) The construction being practically the same as that of a transformer, standard transformer parts may be used to a very great extent, thus reducing development costs and the time required for manufacturing.

Lubrication of Air Compressor Cylinders.—A pamphlet recently issued by the Fidelity and Casualty Company contains the following information relating to the lubrication of air compressor cylinders. Recent disastrous explosions in air compressor systems indicate the danger existing from the use of ordinary engine oil in air cylinders. Only a pure mineral oil with a flash point as high as good lubricating qualities will permit, should be used. An excess amount of lubricant should be avoided. As air receivers are liable to explosion from accumulated oil deposits, every receiver should be equipped with a pressure gauge, safety valve, and proper drains. All reservoirs and pockets in the air line where there might be deposits should be drained frequently and cleaned. It is bad practice to have the air compressor inlet in a hot or dusty room. The air should be as cool and clean as possible. The practice of throwing paraffin oil into the compressor inlet to clean it is extremely dangerous. Lubrication of the air cylinder with soapsuds (preferably made of one part soft soap to 15 parts water) for a few hours each week, or less frequently if the load is light, will aid materially in keeping the cylinder clean. To prevent rust discard the soap and feed oil into the cylinder about an hour before shutting down. The receiver blow-off should then be opened and the accumulation of oil and water drained off.

THE USE OF HEAVY OIL FUEL.

In the course of a paper on this subject read before the American Institute of Mining Engineers, Mr. W. N. Best said that the advent and popularity of automobiles and oil engines had created such a demand for by-products of fuel oil that it had now become too valuable to be used as fuel, notwithstanding its excellent quality. The manufacturing world must, therefore, install in future some system by which heavier oils could be used. Efforts had been made in the eastern parts of the United States during the past year and a half to burn the heavy petroleum from the Mexican fields, which had an average gravity of 14° Baumé. Through ignorance, when attempting to use this oil, no means were provided for heating the fuel in the storage tank; the oil pump which had been used for ordinary fuel was not changed to adapt it for a heavier fuel; the oil pipe lines were not laid so that the fuel would be constantly in circulation. The object of heating the crude oil was to reduce its viscosity, and it should be heated in the storage tank to a temperature that would allow it to be pumped easily. The oil should be heated in the supply and overflow pipes by running a steam pipe alongside of them, and enclosing both in an 8in. square box, which, when the pipes had been tested, was filled with dry sand. By regulating the amount of steam passing through the heater pipe, the oil was supplied to the burners at a temperature just below its vaporising point. When the pipes were enclosed in the manner described only a small quantity of steam was needed, and, by laying the steam pipe below the oil pipe in the box, it was accessible at all times. Some preferred to heat the oil by passing a ⅜in. steam pipe through the oil-supply pipe. The first cost of this was cheaper, but, if the steam pipe should leak, it was difficult to make the necessary repairs. Coating the oil-pipe threads with a paste consisting of litharge and glycerine before assembling would prevent leakage. The unions should be ground joint. Gum or rubber should never be used, and lead gaskets should be used in flanges. Malleable-iron beaded fittings should be used on all oil-pipe lines. The advantage of accurately heating the oil to the desired temperature was shown by some tests in which a saving of 20 per cent. of Mexican crude oil required was made by heating it to 160° Fah. (10° below its vaporising point) instead of 120° Fah. The control of temperature was so important that thermometers should be used in direct contact with the fuel as it passed to the burner. Two or three such thermometers, well located, would save much oil and increase the output of the furnaces. The overheating of the oil might readily be detected by the puffing of the burner, due to escaping vapour.

Power Economics for Intermittent Loads.—In this paper, reproduced in our issues of March 20th and 27th, the author has drawn our attention to two errors. On page 300, line 9 from bottom of first column, the advantage in favour of the electric winding equipment is given as £440. This should read £640. On page 301 the description on the curves, Fig. 7, should read "Percentage of no-load speed" and not "Percentage of full-load speed."

The Incorporated Municipal Electrical Association.—The preliminary programme of the 19th Annual Convention, to be held in Birmingham from June 15th to 20th, has now been issued. An address will be delivered by Mr. R. A. Chattock, president of the association, chief electrical engineer of the Corporation of Birmingham. The papers to be read include the following: "The Commercial Development of Electrical Supply in Towns of Moderate Size," by Mr. W. A. Vignoles, chief electrical engineer of the Corporation of Grimsby. "The Design and Operation of Modern Boiler-house Plant," by Mr. S. E. Fedden, past-president, chief electrical engineer of the Corporation of Sheffield. "The Standardisation of Tariffs," by Mr. J. Horace Bowden, chief electrical engineer of the Corporation of Poplar. Visits are being arranged to a large number of works and places of interest. Communications relating to the Convention should be addressed to the secretary, at 28, Bedford Square, London, W.C.

INDUSTRIAL AND TRADE NOTES.

New White Star Liner.—The White Star Line has, we learn, placed an order with Messrs. Harland & Wolff, Ltd., Belfast, for a steamer of about 33,000 tons gross register, which is intended for the company's passenger service between Liverpool and New York.

Light Railway.—The Board of Trade have recently confirmed the undermentioned order made by the Light Railway Commissioners: Burythorpe Light Railway Order, 1914, authorising the construction of a light railway in the North and East Ridings of the County of York, from Huttons Ambo to Burythorpe.

Opening of an Underground Railway.—On Tuesday last there was opened for public traffic a short extension of the Charing Cross, Euston, and Hampstead Railway. It is a single line continuation in the form of a loop from the present terminus at the Strand near Charing Cross to the Thames Embankment.

Clyde Shipbuilding.—During March there was launched from shipbuilding yards on the Clyde 16 vessels of 24,631 tons, which is the lowest output since 1908, and the third lowest during the past 20 years. For the full quarter, January-March, the Clyde total is the lowest since 1910, and it represents a decrease of nearly 22,000 tons as compared with last year and of nearly 40,000 tons as compared with 1912.

Proposed Certification of Locomotive Engine Drivers.—The compulsory certification of locomotive engine-drivers and motor-men on railways is proposed by a Bill which has been introduced into Parliament by Mr. Thomas with the support of Messrs. Hudson, Wardle, Ramsay Macdonald, and Barnes. It provides that no locomotive engine or motor train shall be driven by or be in charge of an uncertificated driver. The maximum penalties for the employment of non-certified men by a railway company would be £10 for the first offence, £20 for the second, and £50 for subsequent offences.

North of England Ironworkers' Wages Reduced.—The return made to the Board of Conciliation of the North of England Iron and Steel Trade shows that the total output for January and February was 8,794 tons, made up of, in round figures, 6½ tons rails, 1,138½ tons plates, 7,354¼ tons bars, and 294¾ tons angles. Compared with a year ago rails have fallen from 66 tons, plates from 2,112, bars from 10,965, and angles 359 tons, while prices are 10s. 3d. less in the case of bars, plates 2s. 10d. less, angles 12s. 3d. less, and rails 20s. Now that the net average selling price is below £7 there will be a reduction of 3d. per ton on puddling and 2½ per cent. on all other forge and mill wages to take effect from March 30th.

Coal Mines Act Amendment Bill.—The text of Mr. McKenna's Coal Mines Bill to amend the Coal Mines Act in 1911 has just been issued. The two chief clauses are directly due to the Labour complaints after the Cadeby disaster about the impossibility of proceeding against persons whom they held should be answerable for accidents in collieries under their charge. The Bill provides that the provisions of the 1911 Act for enquiries into the conduct of holders of certificates shall be extended to apply to "any owner or agent of a mine taking part in the technical management thereof," if he be alleged to be unfit to continue to hold a certificate of competency. Further, if a coroner's verdict, an inspector's report, or a special report charges non-compliance with the regulations in any pit where an accident has happened, then the Bill proposes that summary proceedings against any person liable to prosecution can be begun at any time within three months of the issue of the coroner's verdict or inspector's report.

World's Coal Production.—A White Paper just published by the Board of Trade shows that the principal producing coal countries and the output of each in 1912 were as follow: United States of America, 477,202,000 tons; United Kingdom, 260,416,000 tons; Germany, 172,065,000 tons; France, 39,745,000 tons; Russia, 25,998,000 tons; Belgium, 22,603,000 tons. Provisional figures for 1913 show an increase of nearly 30,000,000 tons in the United States, and of about 14,000,000 tons in Germany. Expressed in relation to the total population the output in 1912 was greatest in the United Kingdom, averaging 5·7 tons per head, compared with 5·0 tons in the United States, 3·0 tons in Belgium, 2·6 tons in Germany, and 1·0 ton in France. Both as regards the total production and the average output per head in the United Kingdom, the figures for 1912 were lower than those for 1911, owing to the effects of the national strike of miners. In the United States, Germany, and France, however, the figures were considerably higher than those recorded in any previous year. The total coal production of the British Empire in 1912 was nearly 310,000,000 tons. The average value of the coal at the pit mouth varied widely in different countries, being as low as 4s. 6d. per ton in British India and as high as 13s. 5¼d. in Belgium. In the United Kingdom the average value was 9s. 0¾d., an average which in 31 years was exceeded only in 1900 and 1910. The total number of persons engaged in the industry was the greatest in the United Kingdom, where the number employed in 1912 was nearly 1,069,000, of whom 862,000 were employed below ground. The countries importing most largely were France (21,000,000 tons), Canada (13,500,000 tons), and Austria-Hungary (13,500,000 tons).

The Nationalisation of Waterways.—A deputation representing the Waterways Association attended the Board of Trade offices, a few days ago, to discuss the question of the nationalisation of the waterways and canals of the United Kingdom. The deputation was received in private by Mr. J. M. Robertson, Parliamentary Secretary to the Board of Trade. Mr. Neville Chamberlain, chairman of the Waterways Association, in presenting the case for the deputation, said the time had come when the Government should give effect to the report and recommendations of the Royal Commission on Waterways. Communications which had passed between their officials and the local authorities all over the kingdom showed that the latter were ready and willing to accept the principle of contribution to a national scheme of canal development where they were to be specially benefited. The difficulty at the present moment was that there was no definite proposal before the country for any authority with whom they could negotiate. The Association therefore urged the appointment of a Waterways Board as the first step, to be followed by the acquisition of the main water routes of the country to be maintained by one authority, and then proceed gradually to develop and improve the modern standards. In his opinion that did not involve the immediate expenditure of 20 million pounds. On the contrary, the Association shared the view of the Royal Commission that the developments should be gradual and as they were warranted by experience. Mr. J. M. Robertson, in his reply, said he would place the views of the deputation before both the President and Department of the Board of Trade which was concerned. He assured them that these views would receive the most careful consideration.

Oil Resources of the Empire.—At a recent meeting of the Royal Society of Arts, Dr. F. Mollwo Perkin discussed the oil resources of the British Empire. So far as mineral oils were concerned, he pointed out that the whole production of the British Empire represented only 2·06 per cent. of the world's output, while the United States contributed over 60 per cent. and Russia nearly 20 per cent. He calculated that the total annual mineral oil production of the British Empire amounted to 1,359,329 tons, and the two most considerable contributors were India, with 1,000,000 tons, and Scotland, with 275,000 tons. There were, however, abundant indications that the mineral oil supply within the Empire might be largely increased to help to meet in greater measure the ever growing demand for oil fuel for the Navy, the merchant fleet, aeroplanes, and heavy internal combustion engines. With respect to Scotland, he hoped that the production might be increased by utilising the shale deposits that were last year located in Skye. Canada, more particularly Alberta, it was suggested, might prove one of the richest oil fields in the world, and he considered it the duty of the Canadian Government to encourage the opening up of new oilfields and to discourage wild-cat schemes and reckless company promoting. The great shale beds of Tasmania were also indicated as another valuable source of supply, and it was thought possible that a shale oil industry might be established in South Africa. Dr. Perkin suggested that careful geological surveys should be made of all the British Dominions, and that test drills should be made when the conditions seemed favourable for establishing an oil field. He also contended that the British production of coal-tar oils might be largely increased, and experiments made with Scotch peat in his laboratory had convinced him that oil would be profitably extracted from it in the near future.

Tests of Gas Calorimeters.—In a technologic paper recently issued by the U.S. Bureau of Standards the results are given of a critical investigation of eight flow calorimeters, representing types widely used. The investigation has shown that several of the calorimeters that were investigated could be used, when proper precautions were observed and suitable corrections were applied to the observed heating values obtained with them, to determine the total heating values of most kinds of gases to an accuracy of about 0·3 per cent. Some of the calorimeters are, however, subject to constant errors that cannot be eliminated or be readily determined except by comparison with a standard instrument, such errors for one calorimeter amounting to nearly 2 per cent. Examination of a very large amount of data obtained during the investigation indicates that with those calorimeters free from significant constant errors total heating values should be determinable, under conditions obtaining in the practical testing of gas, to an accuracy of the order of 1 per cent.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1913.

Rotary steam engines. Dudley. 1097.
Recovery of copper from its ores and solutions. Sulman, Picard, and Minerals Separation, Ltd. 1152.
Radiators for heating buildings. Frank. 1204.
Internal-combustion engines. Blankenburg. 4086.
Carburetters of internal combustion engines. Ferguson. 5267.
Carburetters for internal-combustion engines. Cox. 5974.
Burner for petroleum. Linley & Co., Owensmith, and Edwards. 6170.
Regulation of internal combustion engines. Neute. 6193.
Metal founding. British Thomson-Houston Company. 6286.
Removal of ammonia from gases. Marr. 6291.
Acetylene generator. Smith. 6503.
Measuring and indicating instruments. Hughes & Hayward. 6566.
Slotting machine for cutting gear-wheels. Jansen. 6701.
Apparatus for counting revolutions and indicating direction of rotation. McNab. 6752.
Valves. Purser. 6759.
Automatic devices for starting motors. Cantono. 7241.
Packing for pistons. Williams. 7903.
Safety device for lifts. Evans. 8158.
Steam turbines. Dianovszky & Schlegel. 8749.
Manufacture of boron-copper. Gleason. 8790.
Valves of internal-combustion engines. Forbes. 9156.
Rotary pumps or blowers. Robertson. 10048.
Stop-valves. W. M. Still & Sons, Ltd., and Adamson. 10904.
Tachometers. Harding. 11484.
Prevention of corrosion of iron and steel. Hanemann & Hanaman. 11966.
Fasteners for driving belts. Blanc. 12803.
Rotary engines. Curtis & Parker. 13425.
Apparatus for carburetting and washing air and other gases. Constantinesco. 13608.
Fluid-pressure engines. Poppe. 13866.
Valve mechanism of internal-combustion engines. Lamplough. 14248.
Nut-locks. Wegener. 15023.
Hydraulic valves. Berry. 15248.
Controlling gear of hydraulic turbines. Gagg. 17327.
Process for converting fine coal into a marketable fuel. Evans. 18270.
Nut-lock. Gray. 18892.
Hydraulic change-speed gear. Hammer. 19335.
Apparatus for controlling from a distance and for regulating the speed of the propelling turbines of a ship. Soc. Anon. Italiana Gio. Ansaldo & Co. 19743.
Journal boxes. Hewitt. 20130.
Packing for rotary engines. Prinz zu Lowenstein. 20133.
Safety devices for steam condensing plants. Muller. 20855.
Manufacturing of brasses. Casimir. 21226.
Centrifugal fans. Hancock. 21353.
Precision instruments for measuring the throw and angular relation of the crank-pins of locomotive wheels. Soc. Lamaziere, and Bunzli, and Lecomte. 22607.
Change-speed gearing for power-propelled vehicles. Royce and Rolls-Royce, Ltd. 25394.
Tools and tool-holders for lathes. Richards, Grayson, & Melsom. 25426.
Carburetters for internal-combustion engines. Smith. 25629.
Fuel saving devices for internal-combustion engines. Wade. 25663.
Rope railways. Thunhart. 27151.
Draw and buffer gear for railway vehicles. Levick. 27325.
Shaft-bearings. Hermant. 28663.
Flexible couplings. Croft, Croft, & Croft. 28762.
Stop-valves. Lentz. 28788.
Traction engines. Fowler & Livsey. 29764.
Water gauges. Klinger. 29904.

1914.

Internal-combustion engines. Herr. 825.
Valves of reciprocating engines. Schmidt. 926.
Internal combustion engines. Rundlof. 3463.

ELECTRICAL, 1913.

Electrically operated steering gear. British Thomson-Houston Company. 1505.
Interrupters for electric circuits. Pollak. 6122.
Electric regulating switches. Miller & Boothman. 6371.
Electric transformer arrangements. British Electric Transformer Company, and Crosbie-Hill. 6799.
Electric cables. Mirza. 6817.
Electric dry batteries. Stern. 6950.
Dynamo regulators. Mellersh-Jackson. 7156.
Switches for electrically operating planing machines. Lancashire Dynamo and Motor Company, and Hargreaves. 7369.
Flame arc lamps. Tate & Monkhouse. 7411.
Fuses or cut-outs for electric circuits. Cox. 9144.
Automatic circuit breakers. Holmes and Kemp-Welch. 13587.
Systems of electric distribution. British Thomson-Houston Company. 13656.
Process for heating articles in electric furnaces. Fischer. 17490.
Ignition systems of internal combustion engines. Varley. 17607.
Multiple-way insulating-sleeve for cables. Mitchell & Cooper. 19212.
Bonding clamp for metal-sheathed electric wires and cables. W. T. Henley's Telegraph Works Company, and Bishop. 20195.
Arc lamps. Dyer & Adams. 23013.
Connections and fittings for electric conduits. Birch. 24777.
Collector brushes for electrical apparatus. Christie. 25465.
Accumulators and electrodes therefor. Svenska Ackumulator Aktiebolaget Jungner. 30082.

1914.

Electrical accumulators. De Sedneff. 1119.
Electrode-holders for electric furnaces. Fried. Krupp Akt. Ges. 5414.

METAL QUOTATIONS.

TUESDAY, APRIL 7TH.

Aluminium ingot	86/- per cwt.
,, wire, according to sizes, &c. ......from	112/- ,,
,, sheets ,, ,, ... ,,	112/- ,,
Antimony	£27/10/- to £29/10/- per ton.
Brass, rolled	7¼d. per lb.
,, tubes (brazed)	9⅝d. ,,
,, ,, (solid drawn)	7⅞d. ,,
,, ,, wire	7⅜d. ,,
Copper, Standard	£65/15/- per ton.
Iron, Cleveland	51/6 ,,
,, Scotch	57/6 ,,
Lead, English	£18/15/- ,,
,, Foreign (soft)	£18/3/9 ,,
Mica (in original cases), small	6d. to 3/- per lb.
,, ,, ,, medium	3/6 to 6/- ,,
,, ,, ,, large	7/6 to 11/- ,,
Quicksilver	£7/-/- per bottle.
Silver	27d. per oz.
Spelter	£21/10/- per ton.
Tin, block	£167/10/- ,,
Tin plates, I.C.	13/- per box.
Zinc sheets (Silesian)	£24/15/- per ton.
,, (Stettin; Vieille Montagne)	£25/2/6 ,,

The Junior Institution of Engineers.—The following programme has been arranged for the present month: April 17th, meeting at 39, Victoria Street, 8 p.m.; Mr. R. S. Fox on "A Few Typical Carburetters." Meeting of the North-western Section at 26, Corporation Street, Manchester, 7-45 p.m.; Mr. J. H. Lester on "Motor Cars, Ancient and Modern." April 18th, visit at 2-30 p.m. to the Australia House, Kingsway. April 20th, ordinary meeting at Institution of Electrical Engineers, Victoria Embankment, 8 p.m.; paper by Mr. James Richardson, B.Sc., Assoc. M.Inst.C.E., on "Lines of Future Development in High-power Diesel Oil Engines." April 21st, meeting of the Midland Section at Imperial Hotel, Birmingham; paper by Mr. R. B. A. Ellis, A.M.I.Mech.E., on "Military Engineering." April 24th, meeting at 39, Victoria Street, Westminster, 8 p.m.; Mr. George Evetts on "A Visit to the Iron Districts of French Alsace." Ordinary meeting of North-western Section at the Municipal School of Technology, Manchester, 7-45 p.m.; paper by Mr. H. T. Hildage on "Some Notes on the Application of Chain Gearing." April 25th, visit at 3 p.m. to the South Metropolitan Gas Company, 589, Old Kent Road, S.E. April 27th, meeting of the Midland Section at Birmingham. May 1st, meeting at 39, Victoria Street, Westminster, 8 p.m.; Mr. S. T. Robson on "The Control and Organisation of the Engineering Profession."

The Mechanical Engineer.
An Illustrated Weekly Journal
Vol. 33, No. 847

Edited by
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Telegrams: "Scientific," Manchester.
Telephone No. 6655 City.

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Advertisements, displayed, for insertion in current issue should reach our Manchester office not later than first post Tuesday morning, and small prepaid advertisements not later than first post Wednesday morning.

State Ownership and Management.

The fallacy of State ownership of mines as a panacea for social and labour troubles is strikingly shown in a paper recently read by Prof. Henry Louis, of the Department of Mining of the Armstrong College, Newcastle-on-Tyne, before the local Economic Society, and we would commend its study to all who pin their faith to this socialistic nostrum. The results of State working mines, where it has been adopted on the Continent and in the Colonies, are given in detail, along with those of the limited application of the principle in this country, where, it may not be generally known, State ownership does exist to some extent. In Cumberland and Durham, for instance, there is a certain amount of publicly owned coal. The Ecclesiastical Commissioners are large royalty owners, and, though not the State, are in a sense a State department, while the crown is the absolute owner of all under-sea coal, and in the Forest of Dean all the coal is practically State owned. A review of the facts and conditions that pertain in these cases clearly disproves the claims put forward by those who advocate State ownership, and which may be briefly summed up as "(1) less waste of valuable coals; (2) lower cost of production; (3) cheaper coal for the consumer; (4) improved labour conditions and higher and steadier wages." These advocates advance no facts in support of their theories, and such as are obtainable go against them. If even a reasonable proportion of the claims could be established there would be some justification for considering them seriously. Take the Forest of Dean, for example. Here royalties are, if anything, a trifle lower than the average of the country, but consumers are in no way favoured in price, while wages are among the lowest in England. It may be argued that the working of a small section is no criterion of the results that would accrue if State working were universal, but it is difficult to see how mere multiplication of area can

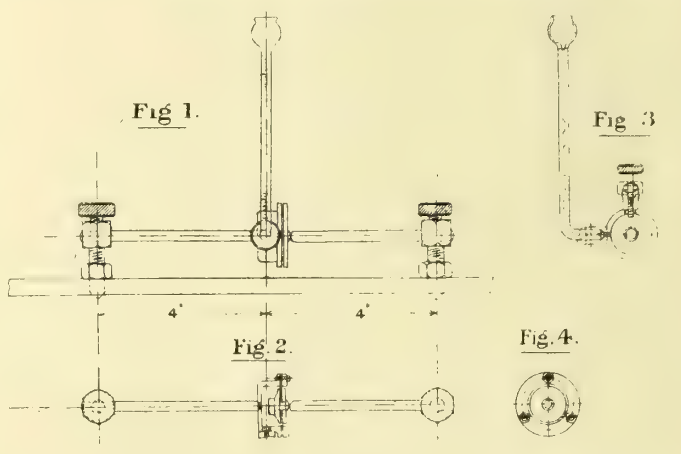
produce an entirely opposite result. In Germany, France, and Belgium the State is the absolute owner, yet in these countries the waste is fully as great as with us, prices are higher, the accident rate is as heavy, strikes are frequent, while, in addition, wages are lower and the conditions of employment worse in every case. The United States have preferred deliberately to alienate their mineral wealth in favour of private development, and experience has proved the wisdom of their policy, the impetus to national industries having more than compensated the State for the royalties relinquished. A study of the capital returns in the State mines of Prussia shows they are a financial failure and that the beneficial expectations of the employés do not accrue. In the State of Victoria, which is noted for its democratic views, there is a coal mine owned and operated by the State which is responsible for some 77 per cent. of the entire output. It has no competitor in its own district, and therefore closely approximates to the ideal conditions of State ownership advocates. A glance at the figures relating to this mine is instructive. The amount spent up to the end of the financial year 1912 was about £170,000, and the profit a little under £10,000, or approximately 5d. per ton, without making any allowance for amortisation or redemption of capital, and the report states that "the mine was idle owing to trouble with the employés from April 4th to May 17th." A summary of Prof. Louis' facts and figures leads inevitably to the conclusion, which we cannot do better than quote, namely, that where adopted "no greater measure of safety has been attained, wages are lower, labour troubles are as frequent, the price of coal is higher, and withal the taxpayer is heavily mulcted for the evils brought about by the State management of mines."

If we turn from mines to railways, experience again presents similar lessons; that of France is particularly illuminating. When the State takes over the management, operating and working expenses invariably increase. On the Western Railway, for instance, taken over in 1908, the operating expenses increased from about six millions sterling in that year to nearly nine millions in 1912, mostly due to wages. In 1908 the wages were roughly a little over three millions, in 1912 they were 5½ millions, an advance of about 55 per cent. Meantime, during this period, freight and passenger rates remained practically unchanged, while the gross receipts only increased about 12 per cent. One-third of the increase in the wages bill, it may be noted, was due to the abnormal increase in the clerical staff. Of the 5,280 additional employés officially reported for 1911 only 1,280 were in the track and train service, while no less than 3,000 were added to the station service, the staffs of which in some cases were doubled, and even trebled, mainly, it is affirmed, to find soft jobs for political nominees. The degenerative effect of Governmental management is further exemplified by some figures in Leroy-Beaulieu's "State Railways of France" regarding the marked increase of sickness among the employés. In 1909 no less than 34 per cent. of those employed in the offices and terminals were granted sick leave. In 1910 the number reached 36 per cent., and in 1911 no less than 45 per cent. A spirit of emulation appears to exist between the various departments in this respect, for the transportation and maintenance branches outshone even the offices and terminals. In 1909, 45 per cent. secured sick leave; in 1910, 48 per cent.; and in 1911, 55 per cent. The explanation is clear; the French railway employé enjoys even better terms than those granted under our own Insurance Act—he gets full pay! Can it be wondered at that malingering should be even more pronounced than it is here, and that Government management should be synonymous with soft jobs, lowered efficiency, and higher cost. The business community has always recognised that private enterprise, where it can be invoked, stands for greater efficiency than State enterprise. Unfortunately a section of politicians appear to think that health and wealth and happiness can be easily created by legislation, but, while its controlling influences may be readily admitted, its creative powers are open to serious question, and it should not be forgotten that any check on the creation of wealth largely diminishes the power to dispense either health or happiness.

THE FOSTER STRAINMETER.*

BY W. R. G. WHITING, M.A.

This instrument depends on the principle of the Bramah's press, and differs from that machine in that a multiplication of displacement and not of force is desired. It is somewhat strange that such an apparently obvious method of recording minute strains has not been, publicly at any rate, employed



before. It is possible that others, having experimented with the idea, were deterred by two inherent difficulties I mention later on. The instrument as ordinarily manufactured is shown in Figs. 1 to 4. The magnification is about 500 times, and is obtained by a volume of liquid equal to that displaced by the motion of a diaphragm about ⅞in. in mean diameter being forced along a glass tube of about 3·5 one-hundredth bore. With tubes of considerably smaller diameter some trouble from capillary action is experienced; larger magnifications are, therefore, best obtained by employing a larger chamber, but one instrument at least has been made having a multiplying ratio of 3,615, obtained by employing a smaller bored tube.

The difficulties referred to are occasioned by temperature change and by leakage. Since water, the liquid employed, has an expansion coefficient varying rapidly with temperature, it has not been possible to obtain automatic compensation by suitable proportioning of the parts. By keeping the volume of the chamber small compared with its area the temperature correction can, however, be made small, and, in fact, zero at a particularly low temperature. The coefficient, however, increases with increase of temperature, and this is an undoubted difficulty in any test prolonged over a considerable alteration of temperatures. Sample instruments are calibrated for this correction and the appropriate coefficients found. Leakage was a most unexpected difficulty, but after

* Paper read at the spring meetings of the fifty-fifth session of the Institution of Naval Architects, April 2nd, 1914.

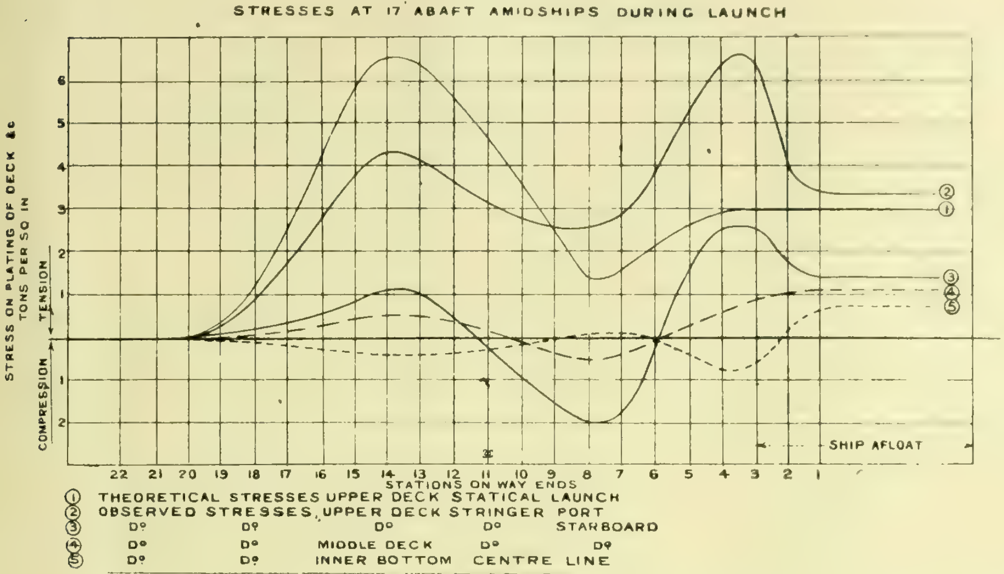
many experiments a suitable packing material was found in chrome leather washers boiled in paraffin wax.

When erected on an 8in. base of steel, the total range of 4in. in the divided tube represents a strain of one-thousandth of an inch per inch. Taking Young's modulus at 13,000, this strain would be caused by a stress of 13 tons, that is to say, each of the 50 divisions corresponds to slightly more than one-quarter of a ton stress. It is quite easy to estimate the fifths of a division, or to one-twentieth of a ton stress. As a test of the capabilities of the instrument under conditions of severe vibration, a pair were mounted, some time ago, on the connecting rods of a screw steering gear of customary type. During the trials of the gear the following results were obtained when going astern:—

Fig 5

BATTLESHIP "A"

STRESSES AT 17' ABAFT AMIDSHIPS DURING LAUNCH



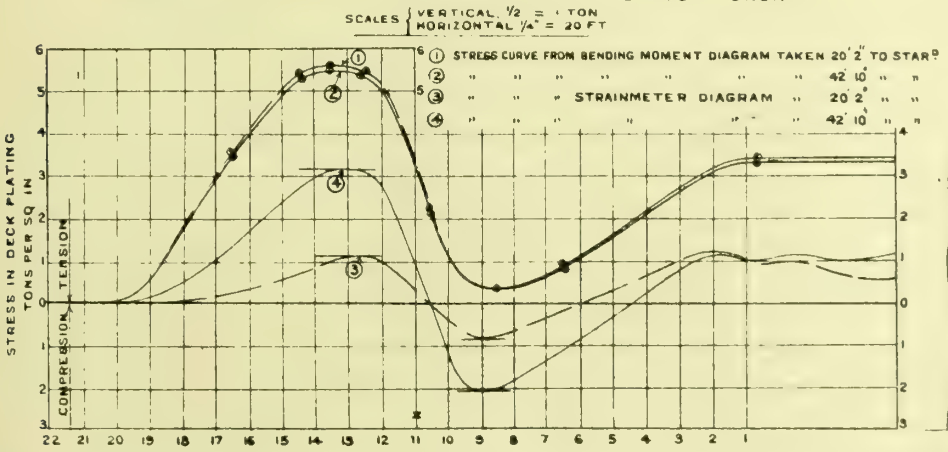
Helm.	Stress in Tension in Connecting Rod.	Compression in Connecting Rod.	Ratio of Tensile to Compressive Stress.	Change of Torque.
	tons/sq. in.	sq. in.		ft. tons.
Centre line to hardover starboard	1·9	·8	2·4	195
Hardover starboard to hardover port	2·75 (total stress differences)	2·75	1·0	390
Hardover port to centre line	1·8	·9	2·0	200
3° starboard to hardover starboard	1·9	1·0	1·9	215

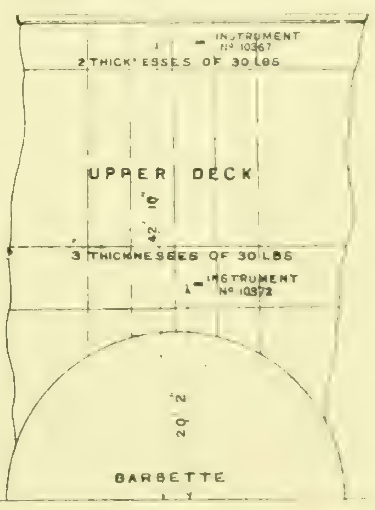
Fig 6.

BATTLESHIP "B"

STRESSES ON UPPER DECK AT 184 FRAME DURING LAUNCH

SCALES { VERTICAL ½" = 1 TON; HORIZONTAL ¼" = 20 FT





The recorded torques were not dissimilar from those calculated and designed for. The great difference in the division of the push and pull forces in the two connecting rods was quite unexpected, and, in fact, screw gears of this type are provided with a slight end play expressly to ensure the balancing of the pull and push forces and thence the annulment of any resultant force on the rudder head. In this case, however, if the records are to be relied on, an unbalanced force of at least 50 tons must have been acting. As the several readings given above seem quite consistent, there is no prima facie case for believing that this unbalanced force did not exist in the trial, nor that a similar state of affairs may not frequently occur in other gears of the same design.

It is possible that the failure to act in the designed manner arises in the following way. As the crosshead moves from the athwartship position one connecting rod has to travel slightly further than the other. This necessitates an endwise adjustment of the right and left-hand screw, which is provided for by a feather and groove coupling at the fore end of the gear. It is suggested that this coupling tends to bind for the following reason, apart from the question of ordinary sliding friction. This latter alone, when the full torque is being transmitted along the control shafting, is estimated to require a force of about 10 tons before endwise motion ensues.

The two shafts on either side of the coupling each take the full torsion up to and just clear of the coupling, and no torsion where they end within the coupling. Hence the whole shaft, and with it the feather or groove, is twisted in a helix of steadily diminishing slope from the commencement of the coupling to the end of the shaft within the muff. Since the shafts are end to end, the most twisted part of the feather lies in the least twisted part of the groove, and vice versâ. If the allowances are small, as indeed they are in this class of work, the two parts jamb as soon as a considerable torque is applied, and before endwise motion can occur a very large longitudinal force has to be employed.

Another interesting result noted was that, going ahead, the rudder appeared to be slightly overbalanced at full speeds, and slightly underbalanced at low speeds. This pointed to a shift of the centre of pressure between the two cases, which might be attributed to a larger impingement of the propeller race on the rudder at high speeds. Another explanation is, that the commonly assumed position for the centre of pressure on a plane surface inclined to a stream line is not the fixed point supposed. It is conceivable that it varies, not only with angle of inclination, but with speed, either absolute or relative to size of the surface. This simple problem, together with the more complicated cases of concave irregularly-

shaped surfaces, could, I think, be closely investigated at some of our laboratories or colleges with great advantage.

By far the largest stress observed in the connecting rods was the momentary one due to the inertia effects. The powerful steering engine, suddenly started up at the distant end of a long line of shafting, produced an action of impulsive type on the connecting rods directly connected to a rudder weighing many tons. Another phenomenon noticed was that the vertical vibration of the stern produced an alternating bending moment on the connection rods of considerable magnitude, and this was very evident in the strainmeters, especially at certain speeds.

Experiments have been made with these instruments by several firms and at least one Royal dockyard on the launching stresses experienced by ships. The first of the records of this nature obtained at Elswick (Fig. 5) is interesting, but not very conclusive. The instruments were in place only a few minutes before the launch, and doubtless initial stresses were already existent. The greatest recorded mean stress on the upper deck plating was about two-thirds of the calculated stress, but as far as ascertainable it occurred at the "drop off," and not at an earlier stage, as was to be expected. The inner bottom results must be taken, I think, as showing that the structural stresses are there masked by the local ones due to varying pressures from the ways.

More recently, the results shown in Fig. 6 were obtained. On this occasion strainmeters were rigged only on the upper deck, one at the stringer and one adjacent to a barbette opening. The plating near this latter was practically held up on shoring from the deck below, and in the result shirked its work, as was to be expected. On this diagram the calculated initial stresses due to "setting up" have been subtracted from the theoretical curve of stress; even so, the observed values appear to be uniformly less (having regard to sign) than the calculated values, whilst the extreme stress difference agrees very nearly with that anticipated.

Considering that a ship's structure consists of an almost infinite number of component parts connected together at various times, under different conditions of support, initial fairness and temperature, it is not perhaps surprising that, when that ship is first subjected to a large structural bending moment, the strains and stresses observed at one or two isolated and arbitrarily selected spots should be somewhat obscurely related to those calculated for a homogeneous body.

We have also tried to obtain the stresses arising from the operation of "dropping the stern" antecedent to boring out the stern tubes. In this case, as in the last, we had the practical object in mind of attempting to decide to what extent a vessel should be structurally completed before permitting these operations to take place. The results, however, have not been so conclusive as those for launching, though similar in sense.

Quite recently the existing Bulkheads Committee has obtained information of interest and value with regard to the stresses in watertight bulkhead stiffeners, by the employment of these and other strainmeters. The results not having been yet presented to the Board of Trade, I am unfortunately precluded at present from describing them.

I have to tender to Messrs. Sir W. G. Armstrong, Whitworth, & Co. my grateful acknowledgments for permitting the publication of these results, whilst certain members of my staff at Elswick have given me much valuable assistance.

Rescue Brigades in Mines: New Home Office Regulations.—The "London Gazette" announces that the Home Secretary proposes to make general regulations under the Coal Mines Act, amending the provisions as to appliances and rescue brigades contained in part four of the General Regulations of July 10th last. Under the draft regulations the use of self-contained breathing apparatus will be made compulsory, but an alternative system from the establishment of rescue brigades will be admitted, by which, in place of the local brigades at the collieries now required, permanent brigades will be maintained at the central stations, and one or more men, according to the size of the colliery, will be trained at each mine to act with the central brigade when summoned to the mine.

TESTS ON A KAPP VIBRATOR.

In 1913 Dr. Gisbert Kapp read a paper before the Institution of Electrical Engineers ("Journal I.E.E.," Vol. 51, page 243, 1913), in which he described a new form of phase advancer invented by him and called the "Kapp vibrator." Messrs. Sandycroft, Ltd., obtained last year a license for the manufacture of these vibrators, and after devoting a considerable amount of time to their study, recently received an order for, and successfully completed the manufacture of, their first vibrator (other than a purely experimental machine). This vibrator has since been put into regular commercial service, and, being the first of its kind, has excited great interest. The vibrator (Fig. 1) is working in conjunction with a 330 b.h.p. induction motor built by Siemens Brothers' Dynamo Works, Ltd., and is installed at the Chemical Works, late H. & E. Albert, South Bank, near Middlesbrough. The motor is a 12-pole machine operated from the system of the Cleveland and Durham Electric Power, Ltd., who supply energy at a pressure of 2,750 volts and a periodicity of 40 cycles per second.

The vibrator is a phase advancer, or exciter, for use with

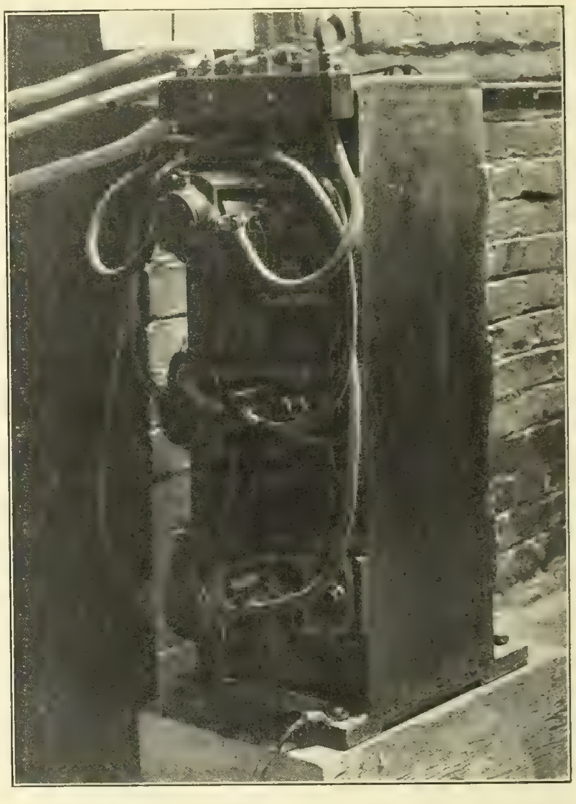


Fig. 1.—The Kapp Vibrator.

induction motors or generators respectively, and consists of a magnet frame carrying three sets of 2-pole field magnets, in which revolve three armatures of the usual continuous-current type. The three armatures are connected in mesh to the slip-rings of the induction motor, as shown in the diagram, Fig. 2, which also shows all the necessary connections (although in some cases it may be desirable to provide an interlocking arrangement to prevent the motor to be started with the vibrator in circuit, that is to say, practically on short-circuit). The field windings are excited with continuous current. The low frequency rotor currents in the armatures cause the latter to rotate first in one direction and then in the opposite direction with the frequency of slip. This rotation induces in each armature a voltage which is opposed to the electromotive force of self-induction of the motor, and is greater than the latter by an amount sufficient to supply through the resistance of the rotor windings the necessary current to produce the magnetic field of the motor. With normal excitation of the vibrator no magnetising current flows in the stator windings, and consequently the motor operates with a power factor of unity. If the exciting current

be increased the greater voltage then induced by the rotation of the armatures will produce in the rotor windings a magnetising current greater than that necessary to produce the magnetic field of the motor, and consequently a leading current will result in the stator windings.

The vibrator, it will be noticed on reference to Fig. 1, is a small and compact machine. The armatures are only 10 cm. in diam., and at full load with a slip of 2·45 per cent. rotate about 3½ revs. in each direction. Since the frequency of supply is 40 cycles per second they change their direction of rotation every half-second. The results of the tests made are plotted in the accompanying curve (Fig. 3), which shows that at half-load the power factor was ·99 leading and at full load ·96 leading. The corresponding power factors without the vibrator were ·76 lagging and ·87 lagging respectively.

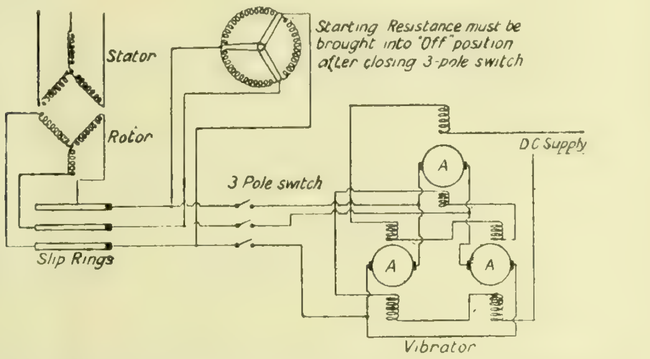


FIG. 2.—DIAGRAM OF CONNECTIONS OF ROTOR CIRCUIT WITH KAPP VIBRATOR.

The machine was guaranteed to give unity power factor from half-load to full load, and when the field current was adjusted for the latter value the excitation loss in the fields of the vibrator was only 50 watts.

The vibrator will work equally well with an induction machine running either as a motor or a generator without change of connections, so that when used with machines driving winding engines or locomotives complete compensation would be obtained under all conditions. A valuable feature of the vibrator is that in the event of any mishap (such as, for instance, the failure of the field) it may be left in circuit, even although failing to fulfil its function as a phase advancer, without affecting the running of the motor with which it is installed. The use of a vibrator improves the operating

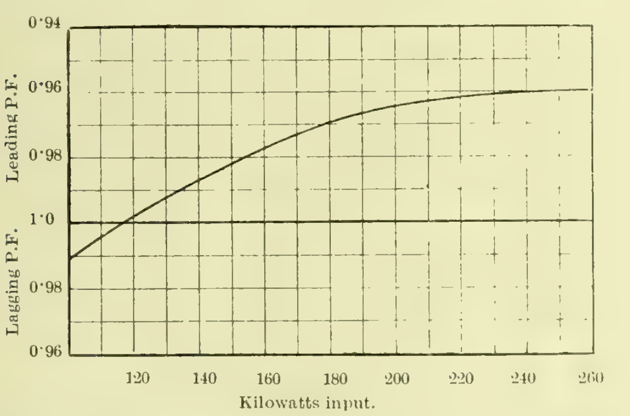


FIG. 3.—POWER FACTOR CURVE OF 330 B.H.P. MOTOR WITH KAPP VIBRATOR.

qualities of a motor not only by correcting the power factor, but also by considerably increasing its overload capacity and maximum torque. Under favourable conditions the efficiency of the motor will be improved. The overload capacity will be increased because not only the stator currents, but also the rotor currents, of the motor will be reduced when the motor is operating above the load corresponding to its maximum power factor.

The vibrator described above was installed to the order of Cleveland and Durham Electric Power, Ltd., and was built at the works of Messrs. Sandycroft, Ltd., near Chester. By the courtesy of the Chemical Works, late H. & E. Albert, it was inspected on March 20th last by Dr. Kapp and a large number of engineers connected with the Newcastle and Teesside local sections of the Institution of Electrical Engineers.

PLASTIC DEFORMATION OF STEEL DURING OVERSTRAIN.*

BY HENRY M. HOWE AND ARTHUR G. LEVY.

IN the plastic deformation of steel by over-strain such as punching, wire drawing, cupping, &c., four distinct phenomena may be observed. There are *inter granular* movements, each particle moving as a whole, with which are closely connected the relative movements of the masses of ferrite, cementite, or pearlite within the grains, designated *intra granular* movements. There is also a disturbance of the relations between the pearlite, ferrite, and cementite, known as *intra-pearlitic* movements and a form of deformation called *crystal unit* slipping. The latter refers to the travel of the minute units past each other, along the slipping planes, giving rise to the slip bands of Ewing and Rosenhain.

In the tests covered in this paper microscopic examinations were made of longitudinal sections through the fractures of tensile test bars of steel of 0·21, 0·40, and 1·45 per cent. carbon, Nos. 2, 3, and 7 in Table I., through the longitudinal section of a wire-rod of bridge-cable steel, which has been drawn part way through a die in the first draft of wire making, No. 5; and vertical sections through holes punched through and sometimes part way through a tank plate and also through steel of 0·40 and 0·78 carbon. In some cases the punching was done with the usual tight-fitting die, and in others with a die much wider than the punch itself, or in short with both cylindrical and conical punching. The deformation in the previously polished upper surface of the tank plate was also examined. The tensile properties of the tensile test bars are given in Table I., and certain details of the punching, including the linear and cubic shortage of the punched wad, are given in Table II.

The *inter-granular* movements are readily seen on a previously polished surface soon after overstrain starts in. Galy-Ache points out that, with the passing of the yield point, grains like those developed by etching appear. The uplift of the grains is greater in cylindrical than in conical punching, which might well be foreseen; but there is a further and unexpected difference in that the matted area throughout which these inter-granular movements occur is wider in conical than in cylindrical punching. This probably represents the greater bending down of both upper and lower surface in conical punching. Further observations are needed to confirm this. We may surmise that the units which act as grains in this uplift represent what were the austenite grains before austenite-pearlite transformation took place. The massing of the ferrite would be greatest in the boundaries of these grains, and hence these boundaries would be the planes of least resistance.

In each case the punched hole is of two parts, the parallel sided and the diverging sided, or the polished "cylinder" and the matte "bell," but there is this striking difference that with the narrow die the divergence begins very near the exit end of the hole, whereas with the wide die it begins about one-third way down from the entrance end. There is the further difference that, with the narrow die, the elongation of the individual ferrite and pearlite masses into hairs or threads is more marked, but that the deformation has been confined to a narrower ring than with the wide die, this latter difference reflecting the wider matting of the polished upper surface with the wide die. Thus with the narrow die the plate as a whole is less bent, but the pearlite and ferrite masses are more sharply bent than with the wide die.

In cylindrical punching the individual ferrite and pearlite masses are drawn out into long hairs, but without great slipping of these masses as such. There is also an exchange of partners, between the crystalline units of which the ferrite and pearlite masses respectively are composed, and no doubt a corresponding exchange on this ultra-microscopic scale between the adjoining surfaces of ferrite and of pearlite. This is especially true of the surfaces of contact between ferrite and pearlite in those regions in which the degree of elongation decreases rapidly as we pass radially away from the imaginary prolongation of the cylindrical surface of the

* Abstract of paper presented at the February meeting of American Institute of Mining Engineers.

punch, but not more true of those contacts themselves than of every neighbouring imaginary plane parallel to them. Where the degree of elongation or travel thus varies radially to the punched cylinder, so that one infinitely thin-walled

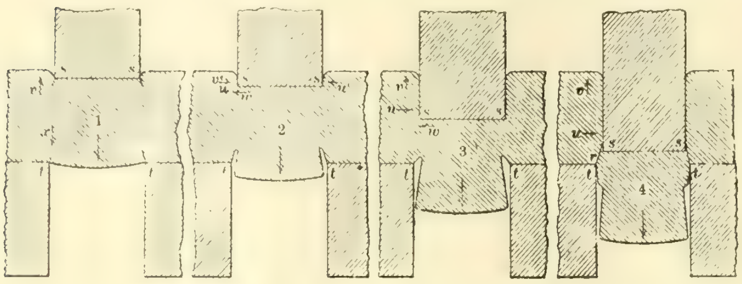


Fig. 1. Probable Course of Flow in Cylindrical Punching.

cylinder lengthens more than that adjoining it, there is an infinitesimal slip of one past the other; and when for infinitely thin-walled cylinders those of crystal-unit thickness are exchanged there comes a like slipping measurable in crystal-unit thicknesses. But though in this sense the actual slip of

hairs, alternately black and white, but the distortion has exceeded the ductility of the metal, and started cracks, which in some cases are only abortive.

A tentative explanation of the various facts is sketched in Figs. 1 and 2, representing stages in cylindrical and conical punching respectively. If the metal were a perfectly mobile liquid, then the pressure would be the same in every direction and at all points. But, because of viscosity, the pressure decreases both as the distance increases from the corners of punch *ss* and of die *tt*, Fig. 1, and as the direction deviates from that of the punching, yet there is very appreciable pressure in all directions. Thus, it is to the upward component, *v* stage 1 of the pressure, that we may refer the forcing up of certain grains at the surface, and the matting of its initial high polish. Again, it is to the centripetal component *u* and *u'*, stages 2 and 3, of the pressure that we refer the high polish or schlickensides in the cylindrical part of the hole, both with cylindrical and with conical punchings. The polish indicates that while the punch was moving down the metal of the plate was forced strongly against it, as at *u* and *u'*. In strong contrast with this polish is the matte surface of the bell, agreeing with our inference that the bell results from a crack starting at or near the corners *tt* of the die.

Table I.—*Chemical Composition and Tensile Properties of the Steels Used in Punching Experiments.*

No.	No. of piece.	Chemical composition. C %	Si %	Mn %	P %	S %	Tensile properties. Tensile strength lbs. per sq. in.	Yield point lbs. per sq. in.	Elongation in 4in. %	Contraction of area. %
1 —¼in. tank plate	T2, T3	—	—	—	—	—	—	—	—	—
2—⅜in. round bar	IV., 7	0·21	0·039	0·053	0·013	0·010	57,385	33,790	29·0	61·9
3 -⅜in. round bar	I., 1	0·40	0·103	0·161	0·014	0·012	69,900	22,480	23·01	36·7
4— { ¼in. plate	I., 251 ; I., 252	0·40	0·103	0·161	0·014	0·012			—	—
4— { ¼in. plate	I., A, B, C, D	0·40	0·103	0·161	0·014	0·012	—	—	—	—
5 ¼in. wire rod	205	0·75‡	—	—	—	—		—		—
6—⅛in. spring plate	C1	0·78	0·108	0·26	0·011	0·013	—	—	—	—
7—⅝in. round bar	IX., 8	1·45	0·14	0·16	0·009	0·006	89,250	35,780	3·8	2·91

Table II.—*Details of Punching of Steel Plates.*

	C per cent.	Loss of volume of wad in punching.* By Measure.	By Weight.†	Lengthwise compression of wad, per cent. of initial thickness of plate.	Cylindrical punching Shortage of diameter of wad, in per cent. of diameter of hole. Top	Bottom	Approximate clearance between maximum circumference of wad and Die. (Inch)	Punched hole. (Inch)	Approximate clearance between inside diameter of hole and die. Inches.	
Tank plate (average of three holes)	low	4·7	10·2	0·4	1·2	1·2±§	0·0065	0·0015	0·005	} ¼in. plunger
I, 251, C	0·40	4·6	14·5	2·4	1·2	1·2±	0·0065	0·0015	0·005	} ¼in. (0·26) die.
					Conical punching.					
I, 252, D	0·40	10·3	4·3	9·7	—2·0‡	7·0	0·025	0·0125	0·0125	} ¼in. plunger.
I, 252, E	0·40	10·0	9·1	6·5	0	8·3	0·0275	0·015	0·0125	
I, 252, F	0·40	11·7	3·7	9·7	—2·0	9·1	0·0265	0·0165	0·010	} ⅜in. (0·385) die.

* Reckoning volume of holes as 100. † Taking specific gravity as 7·85. ‡ The top of the wad is 2 per cent. wider than the top of the hole. § Not determined; the hole and wad are nearly cylindrical.

any one surface is probably very slight, yet the integration of the very many slips at the very great number of surfaces leads to a great total of slip and of slipping friction.

Moreover, this drawing out of a ferrite grain into a ferrite hair means an enormous increase in the ferrite surfaces, and hence an enormous degree of emergence of ferrite crystal units, which initially were in contact with ferrite on all six faces with a given ferrite grain. In short, one face of each unit which has thus moved to the surface of a ferrite hair has, in that motion, exchanged contact with a ferrite particle for contact with pearlite, and yet has preserved continuity, hypothetically through the interposition of Beilby's fluid state.

Our enquiries were not directed specially to the flow which occurs during punching, nor have we gone far enough to form firm convictions about them, but it seems well to record tentative inferences on this subject drawn from some rather striking phenomena. The complete preservation of continuity, so beautifully shown by Tresca in the punching of ductile metals, is lacking in punching 0·40 carbon steel. There has, indeed, been great drawing out of the ferrite and pearlite, especially with the narrow die, into the long

Cracks tend most strongly to start where the deformation is greatest, at the corners *ss* of the punch and at or near the corners *tt* of the die, and once started tend to be extended

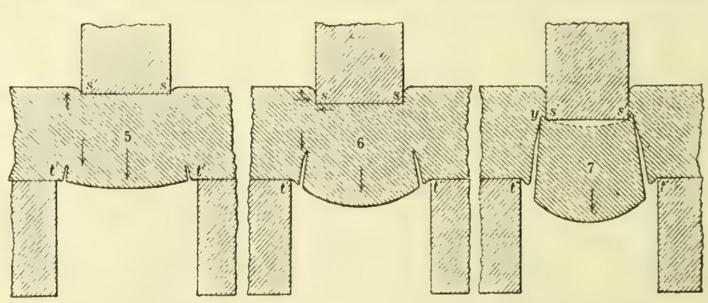


Fig. 2.—Probable Course of Flow in Conical Punching.

by the downward movement of the wad. But the conditions tend more strongly to this extending at *tt* than at *ss*, and in conical than in cylindrical punching, as we will now explain. As regards starting a crack, the conditions at *t*

and s seem to be much alike, in one case the pressing of a sharp edge into the metal and in the other the pressing of the metal against a sharp edge, with the difference that the concentration of pressure is greater at s than at t, as is readily seen if we imagine a plate 1ft. thick punched with a punch only ¼in. diam. This difference represents the centrifugal movement of that part of the metal which lies initially in the path of the punch, in other words, its radial movement, resulting in bulging the plate somewhat in the neighbourhood of the hole, so that the volume of the wad is less than that of the hole.

As between conical and cylindrical punching there is the difference that the pressure on the die corners is weaker in the former at tt than in the latter at tt, both because in the former the pressure is spread out over a longer circumference, and because in the former the tendency to flexure is less at the die corner t, than at a point nearer the axis of the punch. This latter difference is readily seen if we imagine a ¼in. punch driven into a ¼in. plate resting on a 3in. die. Indeed the shoe-heel or burr, which projects down below the edge of the bell at the bottom of Fig. 2, suggests that here the crack started, not exactly at the edge of the die, but little nearer the axis of the punch, either because of local weakness, or because of the stronger bending moment there or for both reasons. The direct measurements in Table II. show that the final clearance between the die and the edge of the wad is about 0·05in. At the time of the starting of the crack it was probably less, because the wad has probably narrowed as it bulged down in the further downward movement. Apart from this there is the difference between top and bottom, that the propagation of the crack started at s is opposed by the strong radial pressure w and u in stage 2. It is to this strong centripetal pressure that we refer the arresting of the cracks. One or more whole rings corresponding to these excisions are often seen in the polished cylindrical part of a punched hole. Here cracks, like that at s in stage 1, have started at various stages during the down-travel of the punch, each starting at the point where the sharp corner of the punch then lay, but their propagation has been arrested and a little ring of triangular cross section has been torn out.

Now comparing conical with cylindrical punching, there is the difference that in the latter the strong pressure x, stage 1, opposing the propagation of the crack by holding together the metal transversely to the path of the crack, has no full equivalent at t, stage 5. This pressure x on the shoulder of the crack tends to bend that shoulder down, through a progressive change from the initially parallel-sided crack, to angles less and less acute as in stage 3, and later even obtuse as in stage 4. Because the vertical component of the pressure transverse to the crack is so much feebler at t' in conical punching than at t in cylindrical punching, the crack at t' is able to extend; and it thus creeps upwards till it reaches a region in which that transverse pressure is strong enough to arrest it, for instance, till stage 6. As the punch moves lower and lower, and the thickness of metal still resisting its further motion decreases, the pressure due to that resistance decreases simultaneously, and with it the component of that pressure transverse to the path of the crack, and with that also decreases the resistance of the further propagation of the crack, which thus continues creeping upward till, as in stage 7, it reaches the cylindrical hole already formed. From this comes the fact that the wad is conical throughout, lacking wholly any cylindrical part representing the cylindrical part of the hole.

But even in cylindrical punching there may be a short conical or bell part at the very bottom. The genesis of this is suggested in stage 4. At a stage intermediate between 3 and 4 the solid metal of the plate is once again pressed against the sharp corner of the die, and this starts a new crack quite as the first crack in stage 1 started. But by this time there is so little remaining thickness of metal resisting the punch, and the pressure which its resistance sets up is therefore so slight, that the component of that pressure transverse to the crack is no longer strong enough to arrest its propagation, and hence it creeps upward till it reaches the down-growing cylinder. This intersection releases the last of the resistance to the forward movement of the punch, save the slight frictional resistance against the sides of the hole, and hence releases the pressure within the metal of the plate, and the pressure on the top of the little bell r of stage 4, leaving it sharp and straight edged.

This individual bell has cut through. But had it started somewhat earlier, while there was still enough pressure to force its upper wall down the latter might be carried down past the corner of the die, giving rise to a thin plate-bottom burr, such as usually forms in cylindrical punching. A preliminary examination of the cylindrically punched holes indicates that part of the circumference of the lower edge of the hole may have such a bell, and the rest of it such a burr, but that burr and bell do not occur in the same place. Indeed, if we have sketched their genesis aright, they are mutually exclusive. The intersection of the bell-shaped crack with the cylindrical hole might conceivably occur at the very corner of the punch, but it might also occur somewhat above that corner, as was the case in our conical punchings, leaving the wad-top burr y of stage 7. In cylindrical punching a similar but smaller wad-top burr forms in like manner.

The reason why conical punching weakens a plate less than cylindrical punching, in cases in which both are unpalliated by either reaming or annealing, is probably that it thus favours the propagation of the crack which starts at or near the corner of the die. At any given instant it is only the metal not yet cracked through that still opposes the downward movement of the punch. Hence the early and rapid propagation of the crack in conical punching reduces early and quickly the resistance to the entry of the punch. Moreover, less resistance means less pressure within the plate, less friction between those parts of the plate already perforated and the punch, and less friction between the particles of ferrite and of pearlite which are dragged past each other from their initial equiaxed shape. In like manner the smaller pressure and smaller overstrain of the metal might confine the damage to metal in conical punching to a narrower ring.

These considerations furnish the explanation of the striking fact that with the narrow die the distortion, as indicated by the length of the zebra markings, increases from top to bottom of the hole. With the wide die it decreases from the top of the bell down. Indeed at the lower end of the bell the arrangement of the ferrite and pearlite does not clearly disclose any distortion at all, and we need the presence of the heel-shaped burr at the bottom of the bell to assure us that there really has been material distortion. Again, the decrease in the amount of deformation from top to bottom in the conical bell agrees with the conception that the crack which forms that bell starts at or near the edge of the die and creeps up, instead of starting at the edge of the punch and creeping down, because this deformation would naturally cease, or diminish very greatly, in any given region, at the moment when the crack extended beyond that region. An even closer measure of the extent of the deformed and embrittled region could probably be had by examining the difference of potential, on a surface cut tangentially to the punched hole, the cutting plane being parallel to the axis of the punch.

The Institute of Metals.—Prof. E. Heyn, of Berlin, one of the most famous scientists in Germany, is this year to deliver the annual May lecture before the Institute of Metals. Prof. Heyn, who has made a life-long study of the subject, has given the title of his discourse as "Internal Strains in Cold Wrought Metals and Some Troubles Caused Thereby." The Institute of Metals is fortunate in its May lecturers, and in the natural sequence of the subjects dealt with at these lectures. Thus, the last May lecture, by Sir J. Alfred Ewing, K.C.B., F.R.S., was on the subject of "The Inner Structure of Simple Metals," and previously Dr. G. T. Beilby, F.R.S., had lectured on an allied subject, "The Hard and Soft States in Metals." Prof. Heyn's discourse will be given in the building of the Institution of Mechanical Engineers, Storey's Gate, Westminster, S.W., under the chairmanship of Admiral Sir Henry Oram, K.C.B., F.R.S., the President of the Institute of Metals, on Tuesday, May 12th, at 8-30 p.m. The secretary of the Institute, Mr. G. Shaw Scott, M.Sc., of Caxton House, Westminstser, S.W., will be glad to forward tickets to any readers who may desire to be present at the May lecture.

SPEED CONTROL OF ALTERNATING-CURRENT MOTORS.

In the course of a paper read before the Pittsburg Section of the American Institute of Electrical Engineers on March 10th, Mr. G. E. Stoltz presented the details of a practical scheme for controlling the speed of alternating-current rolling mill motors. Rheostatic control was, he remarked, satisfactory for use in conjunction with a flywheel, for moderate speed reductions, where the load was constant, but when the load momentarily went off, the speed rose to near synchronism. Multi-speed motors, having two separate windings on both stator and rotor, were satisfactory for two speeds. For more than two speeds this scheme was both expensive and inefficient. The use of two motors connected in cascade provided four different synchronous speeds. This scheme was expensive, and not very efficient, and the control was complicated. The characteristics of the polyphase commutator motor were similar to the direct-current motor, but the additional reactance voltage, due to the pulsating current which was not present in the direct-current motor, introduced commutation difficulties. The inherent characteristics were such that good commutation was obtained at the expense of poor power-factor, and vice versâ.

An installation had recently been made which provided exact speed control over a wide range, with the speed at any setting constant, irrespective of the load on the mill. Unlike rheostatic control it was economical, and consisted of standard apparatus throughout, presenting no complications in operation or repair. This apparatus consisted essentially of a standard wound-secondary mill motor, connected to the mill directly, or by means of a gear, rope or belt drive. The secondary slip rings were connected electrically to the slip rings of a rotary converter with the same number of phases as the secondary of the mill motor. Its frequency and rating must be consistent with that obtained from the secondary of the large motor under operation. The maximum speed reduction in this installation was 30 per cent., which on a 60-cycle system was equivalent to 18 cycles on the secondary. As the locked secondary voltage of the main motor was 552 volts, the secondary voltage corresponding to 18 cycles was 166, corresponding to 272 volts on the direct-current end of the three-phase rotary converter. The direct-current terminals were connected to the direct-current machine of a motor generator set, the alternating-current machine, a standard squirrel-cage motor, being connected directly to the three-phase line. Each of these machines had a capacity equal to 30 per cent. of that of the main mill motor.

In operation, the converter took current from the secondary of the mill motor, and returned it, through the motor-generator set, to the line, the squirrel-cage machine acting as an asynchronous generator when running above synchronous speed. The synchronous speed of the mill motor under these conditions was equal to 60 cycles minus the frequency of the converter, which depended on its speed, which, in turn, with constant field excitation, depended on the voltage impressed across its direct-current terminals. This voltage, and hence the speed of the converter, and the speed reduction of the mill motor, depended on the excitation of the direct-current machine of the motor-generator set. At maximum excitation the mill motor speed was reduced to 30 per cent. At zero excitation the speed of the mill motor would be the same as if its secondary was short-circuited. With the fields reversed, and full excitation applied, the mill motor would run approximately 30 per cent. above synchronous speed. In this case the speed of the motor-generator set dropped below synchronism and the squirrel-cage machine drew power from the line, feeding it through the rotary converter into the mill motor, which thus received power at both its primary and secondary terminals. The speed characteristics of the outfit could be designed to give the motor practically constant speed, regardless of load, or to provide sufficient speed drop to take advantage of a flywheel. The complete outfit had a full-load efficiency of 84 per cent., with a speed reduction of 30 per cent.

Fatal Boiler Explosion on British Destroyer.—As a result of the bursting of a boiler tube in H.M.S. "Albacore," at Chatham on the 6th inst., one stoker was killed and two others so seriously injured that they subsequently died.

BLASTFURNACE "BEARS."

At a meeting of the Cleveland Institution of Engineers, held at Middlesbrough on the 6th inst., Dr. J. E. Stead, F.R.S., read an interesting paper on "Blastfurnace Bears and What They Teach Us," in the course of which he defined a blastfurnace bear as a solidified mass of metal below the hearth or floor level of a blastfurnace found after the furnace had been blown out after long service. During the life of a furnace the hearth floor, generally made of firebrick, was slowly acted upon by the metal and much of it eventually passed out with the slag into the slag ladle. The result of this was that in time a hole many feet deep was formed. Into this pig or hole liquid metal remained and more of it could be removed viâ the tapping hole. The metal sometimes not only worked its way downward, but after reaching a considerable depth, acted upon the brickwork laterally and travelled sideways. Sometimes the metal passed through the walls of the furnace foundations and then worked its way upward, and escaped, doing damage, causing great inconvenience to the workmen, and leading occasionally to serious damage. When the furnace was blown out, the whole of the liquid metal below the level of the tapping hole eventually became solid and constituted the blastfurnace "bear," called in the north-east of England district "an old horse," and in Germany "a sow." The bears when taken out of the furnace hearths weighed from 20 tons to several hundred tons. To remove them they had to be drilled and blasted bit by bit, a process involving considerable labour, cost, and time. The "bears" taught the practical smelter that during the working of his furnace he had been continually losing metal and storing up a substance of much less value than it would have been had it been run out and cast into pigs. The large apparent amount of pure graphite found in the "bears" had led to the trial of carbon and tar concrete, and solid carbon bricks had recently been introduced and put into use. The concrete hearths had failed, and the solid carbon bricks had not been long enough in use to justify any definite conclusion being formed as to their resisting quality. Diamonds, it was alleged, had been found by some German chemists in "bears," and Moissan actually produced diamonds by suddenly chilling highly heated and carburised iron in crucibles. The contraction of the outward solid envelope on the interior fluid and solidifying metal produced enormous pressure, which induced a portion of the excess carbon to assume the diamond instead of the much lighter graphitic form of carbon. These manufactured diamonds had to be highly magnified before they could be seen. The largest ever produced measured not more than half a millimetre in diameter. After describing interesting "bears" found in Cleveland blastfurnaces, the author concluded by saying that there were many things furnace "bears" might teach them, possibly materials not yet discovered, and possibly diamonds, for the enormous pressure exerted on the internal metal during the contraction of the outer portions at the time when the carbon tended to separate as graphite, was just the condition favourable for their formation. To the geologist and mineralogist, "bears" should be most interesting, for there was no short line dividing the metallographist and the geologist or the meteralogist and the mineralogist.

North of England Institute of Mining and Mechanical Engineers.—A meeting of the members of this Institute was held in Newcastle on the 4th inst., the President (Col. W. C. Blackett) in the chair. A paper was read by Mr. W. C. Mountain on "Notes on the Utilisation of Exhaust Steam for Collieries, Ironworks, &c., and the Cost of Electric Current Generated." A mine-signalling apparatus was exhibited, described, and demonstrated by the British Electrical and Manufacturing Company.

The Institution of Mechanical Engineers.—An ordinary general meeting will be held in the Meeting Hall of the Institution on Friday, April 24th, at 8 p.m., when a paper on the "Application of Electrical Driving to Existing Rolling Mills," by L. Rothera, B.Sc., London, will be read and discussed. The anniversary dinner will be held at the Connaught Rooms, Great Queen Street, London, on Thursday, April 23rd. The conversazione will be held at the Institution on Thursday, May 21st.

THE ELASTICITY AND ENDURANCE OF STEAM PIPES.*

BY C. E. STROMEYER.

(Concluded from page 338.)

PROF. BAUTLIN carried out some experiments on U bends shaped as shown in Fig. 8.† As the bends were not square, other but similar formulæ to the above had to be constructed for estimating the displacements of the flange C. These are recorded in the columns marked "Est." in Table IV. The observed displacements are to be found in the columns marked "Obs." This table also contains the dimensions, materials, and other details about the curved pipes or bars. The modulus of elasticity of the cast-iron pipe was 7,870 tons per square inch.

The formula for these bends is:—

$$\triangle = 17{\cdot}27\ X \cdot R^3 : E \cdot I \text{ and } S = \triangle \cdot D \cdot E : 17{\cdot}27\ R^2.$$

It must not be overlooked that, whereas in the previous case (Fig. 7) the height H of the bend is 2 R, in the present case (Fig. 8) it is 3·414 R. The agreement for the mild-steel rods between the estimated and observed displacements is satisfactory, but pipes seem to be rather more elastic than was to be expected. The discrepancies between the estimated and the observed displacement for the mild-steel pipe A have been explained as being due to slight puckers on the insides of the bends of the pipes. In part they are also due to the thinning, during the bending operations, of the outsides of the bends. Generally speaking, Prof. Bautlin's important experiments confirm the mathematical estimates of the deformations of bent pipes, and these may, therefore, be applied to the few exploded steam pipes for which the probable alternating stresses have already been calculated.

It is very unfortunate for investigations like the present one into the mechanical causes of explosions that the Board of Trade reports contain so little information about those parts which, in the opinion of the reporting surveyors, are not the direct causes of the explosions. Thus, amongst about 100 reports on steam pipe explosions, which it is believed were brought about by want of elasticity, the diameters of the pipes and the thickness at the point of fracture are given, but rarely is any mention made of the lengths or the elasticities of these pipes, although these are the determining factors.

For the purpose of this paper, these lengths, as well as the radii of curvature, had to be approximately ascertained by scaling them with the help of the diameters as sketched. It is therefore possible that the dimensions which have been adopted in the following calculations are not always correct.

U bends (Fig. 9) with central branch do not seem to have failed, and this case need not be discussed.

L Bends and Simple U Bends (see Fig. 10). The following formula for the displacement δy in the case of L bends and of $2\ \delta y$ for U bends can be determined in terms of the horizontal pull Y and the bending moment M, by combining the formula in Table I. for the cases represented by Figs. 1, 2, and 5. As there is no pull X, and as the sums of the deflections of the length L and the bend is naught, Y can be eliminated, and M can be expressed in terms of S_b, the maximum bending stress.

$$\delta y = 0{\cdot}712\ S_b \cdot R^2 (L + 0{\cdot}65\ R) : E \cdot D (L + R).$$

For copper E = 8,300 tons per square inch, so that

$$\delta y = S_b\ R (L + 0{\cdot}65\ R) : 11{,}600 \cdot D \cdot (L + R).$$

This formula has been used in calculating the displacements δ_y for the following L bends, and $2\delta_y$ for U bends, $\pm\ S_b$ being the fatigue stresses which have been previously determined (Table I.) for the several cases.

TABLE IV.—*Professor Bautlin's Experiments on the Elasticity of Bends.*

DIMENSIONS, &c.

Details of Bends.	Height. Inches.	Outside Diameters and Thicknesses. Inches.	Moment of Inertia I.	E. I. Millions.
A, Mild steel pipe	94·7	8·7 × 8·2 × 0·26	27	810
B, Mild steel pipe	88·8	5·3 × 5·1 × 0·175	2·65	80
C, Cast-iron pipe	94·7	8·5 × 8·4 × 0·78	139	275
D, Mild steel rod	54·6	3·14 square	8·0	240
E, Mild steel rod	62·5	3·14 square	8·0	240

TEST RESULTS.

Difference between two successive Thrusts in Pounds. Estimated and Observed Displacements of Flange C. Inches.

	220		440		660		880		1,325		1,980		2,420	
	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.
A	—	—	—	—	·30	·68	—	—	·60	1·37	·90	2·16	1·10	2·96
B	·84	·69	1·67	1·42	—	—	—	—	—	—	—	—	—	—
C	—	—	·06	·10	—	—	·12	·22	·17	·33	—	—	—	—
D	—	—	—	—	·19	·24	—	—	—	—	—	—	—	—
E	—	—	—	—	·30	·33	—	-	—	—	—	—	—	—

The elastic limit was reached with pipe A with a thrust of 1,980lbs.

Report No. 958 deals with the two separate L bends, made of electro-deposited copper of 5in. external diameter hooped with iron bands. The starboard (shorter) length, in which, according to the sketch, L and R seem to be respectively about 11in. and 57in., failed, as already stated, after 12 months' running. Assuming the correctness of the previously found alternating stresses of ± 6·2 tons per square inch, the relative movements of the two ends of the pipe should by the formula be ± 0·38in. In the port (longer) branch, L and R seem to be respectively 75in. and 68in. Assuming the correctness of the previously found stresses of ± 5·74 tons per square inch, the relative movements of the pipe ends should be ± 0·25in.

Report No. 1,049 deals with another L bend of solid drawn copper of 5¾in. external diameter. According to the sketch, L and R seem to be respectively 80in. and 25in. Assuming the correctness of the previously found alternating stresses of ± 5·65 tons per square inch for the first failure after 2½ years' running, the relative movement of the two ends of the pipe should be 0·049in. for the second failure after 12 months' running, for which the alternate stresses would be ± 6·02 tons, the relative movements should be 0·051in. The comparative smallness of these relative movements are due to the great rigidity of the small bend, which was only five times as large as the diameter of the pipe. In fact the pipe very probably acted as a stay between the engine and the boiler, and restricted their movements while being fatigued. Had the relative movements been larger and the stresses intenser

* Paper read at the spring meetings of the fifty-fifth session of the Institution of Naval Architects, April 2nd, 1914.

† "Zeitschrift des Vereins Deutscher Ingenieure, 1910," Vol. LIV., p. 43. Also "Mitteilingen über Forschungsarbeiten des Vereins Deutscher Ingenieure." Vol. XCVI.

the failures would have occurred sooner, as happened in the two following cases.

Report No. 1,181 deals with an L bend of solid drawn copper, 6$\frac{7}{8}$in. external diameter. According to the sketch, L and R seem to be respectively 42in. and 50in. Assuming the correctness of the previously found alternating stresses of ± 10·57 tons per square inch for the failure, which occurred after 24 hours' heavy weather immediately after previous annealing, the relative movements of the ends of the pipe should be 0·27in. Seeing that the estimated alternating stresses during the previous 10 years' running were only ± 5·27 tons per square inch, the relative movements of the pipe ends during this longer period do not seem to have exceeded ± 0·14in.

Report No. 1,954 deals with an L bend of sheet copper, 4·92in. external diameter. According to the sketch, L and R seem to be respectively 93in. and 32in. Assuming the correctness of the previously found alternating stresses of ± 13·85 tons per square inch for the new pipe, which failed during a run of four hours in very heavy weather, the relative movements of the ends of the pipe should be ± 0·23in. For the old pipe, which failed after eight years' running under stresses of ± 5·33 tons per square inch, the relative movements should be ± 0·09in.

Report No. 1,355 deals with an L bend of solid drawn copper, 5·19in. external diameter. According to the sketch, L and R seem to be respectively 70in. and 100in. long. Assuming the correctness of the previously found alternating stresses of ± 5·62 tons per square inch, the relative movements of the ends of the pipe should be ± 0·39in.

Report No. 1,543 deals with a U bend of solid drawn copper 4·94in. external diameter. Judging by the sketch, L and R seem to be respectively 16in. and 46in. long. Assuming the correctness of the previously found alternating stresses of ± 5·52 tons per square inch, the relative movement of the ends of the pipe should be ± 0·26in.

Report No. 2,021 deals with an L bend of solid drawn copper, 5·5in. external diameter and 0·25in. thick. According to the sketch, L and R seem to be respectively 68in. and 42in. Assuming the correctness of the previously found stresses of ± 5·61 tons per square inch, the relative movements of the ends of the pipe should be ± 0·17in.

These and the previous estimates are summarised in Table V. They are all based on the empirical formula, which correlates the fatigue stresses for copper and the number of their repetitions up to the point of failure. The experiments on which it is based are comparatively few, and more comprehensive ones will shortly be carried out on a new fatigue testing machine which is nearing completion, but, seeing that the results of fatigue tests with mild steel are very consistent, the intended further experiments on copper will probably merely confirm those already obtained.

Table V.—*Estimated Intensities of Fatigue Stresses and the Relative Movements of the ends of the Fractured Pipes.*

Report Number.	Assumed No. of Vibrations.	Estimated Fatigue Stresses. Tons per square inch.	Estimated Fatigue Movements. Inches.
Failures due to vibrations of the Engines.			
958 (1)	15,000,000	± 6·02	± 0·38
,, (2)	31,000,000	± 5·74	±0·25
1049 (1)	40,000,000	± 5·65	± 0·049
,, (2)	15,000,000	± 6·02	± 0·051
1181 (1)	150,000,000	± 5·27	±0·14
,, (2)	86,000	±10·57	±0·27
1954 (1)	120,000,000	± 5·33	±0·09
,, (2)	14,000	±13·85	±0·23
Failures due to loose Engine Seatings.			
1355	44,000,000	5·62	± 0·39
1543	60,000,000	± 5·52	±0·26
2021	45,000,000	5·61	0·17

Assuming the correctness of the empirical formula then, judging by the estimates contained in Table V., relative movements between engines and boilers of ± 0·38in. (see No. 985) or more should be allowed for. These were associated with fatigue stresses of ± 6·02 tons per square inch, which exceed the fatigue limit of ± 4·3 by 1·7 tons per square inch. If these relative movements of ± 0·38in. had not exceeded ± 0·27in. the pipe would not have failed. Had the pipe been made of steel it would also not have failed, for although its modulus of elasticity is 13,000, as against 8,300 tons per square inch for copper, the respective fatigue limits are 10·3 and 4·3 tons per square inch, and the maximum relative movements to which such a steel pipe would have submitted without injury would have been ± 0·43in. Conversely if a steel pipe of the above dimensions were replaced by a copper one and the relative movements of its ends were maintained at ± 0·43in., then the fatigue stresses in the copper pipe would be ± 6·77 tons per square inch, or ± 2·47 tons above the fatigue limit of ± 4·3 tons, and the copper pipe would fail after 3,600,000 repetitions. This means that if any copper pipe were to fail after experiencing three and a half million stress cycles, which corresponds to 42 days' continuous running of the engines at 60 revs. per minute, and if it were to be replaced by a steel pipe, this would last for ever, and, as most of the pipes dealt with in the Board of Trade reports did last longer than 42 days, the number of explosions would have been correspondingly reduced if steel pipes had been used instead of copper ones.

But—and this is a point which should on no account be overlooked—it is highly probable that the cast-iron valve cases to which these steel pipes would have to be attached would have fractured at an early date, because the resisting moments of steel pipes are 13,000 : 8,300 = 1·56 times as great as those of copper pipes of the same dimensions; and even copper pipes are occasionally strong enough to fracture the cast-iron valves to which they are attached, as is evident from the following Board of Trade reports:—

No. 389.—A copper pipe with fairly large bends broke the neck of the valve chest to which it was attached.

No. 556.—The thrust on an expansion gland, acting at the end of a copper pipe as a lever, broke the neck of the valve chest to which it was attached.

No. 971.—A copper pipe which was attached to the end of a combined expansion gland, stop valve, and throttle valve casing, broke the latter.

No. 1,072.—A copper pipe broke the cast-iron neck of a complicated chest to which it was attached. The other end of the pipe formed part of an expansion gland, which was attached to the engine whose lateral motion was the cause of the fracture.

No. 1,177.—A copper U bend between a boiler and its engine, acting on the end of a throttle valve casing, broke it.

No. 1,572.—The thrust of an expansion gland acting at the end of a copper bend broke the valve casing to which it was attached.

In the following cases the pipes were of wrought iron:—

No. 1,230.—A straight wrought-iron pipe between an expansion gland on the engine and a short cast-iron bend on the boiler stop valve broke the neck of the latter.

No. 1,404.—A straight iron pipe, which ended in an expansion joint, broke the neck of the valve casing to which it was attached.

The following rather unusual failures may be due to bad material, but seeing that they occurred both with sheet copper pipes, solid drawn ones, and electro-deposited ones, it is not unlikely that they were due to fatigue stresses. However, as all these cracks are along the neutral line of the copper bends where there are no bending stresses, but where the shearing fatigue stresses are a maximum, it is not unlikely that these alternating shearing stresses were relatively more intense than the bending stresses near the flanges. It should also be remembered that the fatigue limit for shearing stresses is only about ± 2·5 tons per square inch.

No. 1,231 deals with a sharp bend of sheet copper 3·55in. external diameter, which cracked near the brazing line, which is also the neutral line of the bend. The bend was eight years old when it failed.

No. 1,262 deals with a bend of sheet copper 10·2in. external diameter, which cracked near the brazing line like

the above-mentioned bend. This pipe failed after 16 months' work.

No. 1,662 deals with a bend of solid drawn copper 6½in. external diameter, which failed along the neutral line after three years' work, when it was repaired and annealed, but it failed again after seven years.

No. 1,839 deals with an expension bend of solid drawn copper 5·42in. external diameter, which failed along the neutral line after nine years' work. Locally the tenacity was reduced to 5·6 tons with no elongation.

No. 1,882 deals with a bend of solid drawn copper 5·2in. external diameter, which failed along the neutral line after three years' work. It had probably been damaged locally while being repaired. Locally the tenacity was reduced to 7 tons with 1·5 per cent. elongation.

No. 2,110 deals with an expansion bend of solid drawn copper 5·4in. diam., which failed along the neutral line after four and a half years' work.

No. 2,140 deals with an expansion bend of solid drawn copper 6½in. external diameter, which failed along the neutral line after six years' work.

No. 986 deals with a bend of electro-deposited copper 3⅞in. external diameter, which failed along the neutral line after three years' work.

No. 1,383 deals with a bend of electro-deposited copper 4·8in. external diameter, which failed along the neutral line after seven years' work, close to a repair sleeve which had been brazed on three months before the explosion.

No. 1,736 deals with a bend of electro-deposited copper 3·8in. diam., which failed after one year's work. The tenacity was locally reduced to 12·5 tons with 5 and 8 per cent. elongation.

No. 1,770 deals with a bend of electro-deposited copper 5·4in. external diameter, which failed after two years' work. The tenacity was reduced from about 13·5 tons with 45 per cent. elongation to between 9 and 10 tons with 5 to 7 per cent. elongation.

No. 2,163 deals with an expansion bend of electro-deposited copper 6in. external diameter, which failed along the neutral line after six years' work.

If, as seems probable, the above 12 failures (about 8 per cent. of the total) were due to shear fatigue stresses, which are severest along the neutral lines of beams, they would indicate that the bends had been subjected to more complicated forces than have been assumed when dealing with the other failures, but in the absence of any details about the relative movements of the engines and boilers it is fruitless to venture on any estimates, except to say that the formula for torsion fatigue stresses should be applied to these cases, and that the stresses which are due to the internal steam pressures should not be overlooked.

While studying those Board of Trade reports which seemed to have a bearing on the present question, it was noticed that many copper pipes had failed shortly after being annealed, although until then they had worked satisfactorily for years. This experience would suggest, either that annealing does not remove the effect of fatigue stresses, or that, if carried out injudiciously, it changes tough copper into a brittle material. In the following list of reported cases the numbers in brackets denote the periods in months which elapsed between the dates of annealing and of failure:—

Pipes of brazed sheet copper.—Nos. 1,922 (4), 1,210 (5), 1,021 (6), 2,105 (17), 1,011 (19), 1,443 (23).

Solid drawn copper pipes.—Nos. 1,839 (½), 1,926 (2), 1,709 (5), 1,327 (6), 1,327 (8), 1,993 (9), 1,187 (10), 2,003 (21), 2,110 (36), 1,898 (48).

Electro-deposited copper pipes.—Nos. 1,164 (3), 1,501 (12), 970 (12), 1,610 (19).

The average life of a copper pipe after being annealed seems to be about one year for each one of the above three groups, but, as already suggested, these cases do not prove that annealing is or is not a remedy for fatigued copper. Then also, this experience as regards copper does not apply to steel pipes.

As a safeguard against fatigue stresses in steam pipes expansion glands are sometimes fitted, but they are not always applied where wanted; they sometimes stick fast, and if badly designed, the pipes blow out of their sockets.

This latter class of accidents is illustrated in reports Nos. 779, 1,702, 2,246.

Pipes which stuck fast in their sockets and did not take up the movements are to be found in the following reports Nos. 283, 1,296, 1,104, 1,666, the last being a doubtful case.

In the following cases the thrusts of the pipes in the glands acting on long bends fractured these near their roots, or the glands had stuck fast and the fractures were due to fatigue Nos. 556, 1,113, 1,187, 1,207, 1,230, 1,343, 1,489, 1,572, 1,583, 1,605, 1,609, 1,852, 1,978, 1,916. These are mostly marine cases.

In the following cases the expansion glands neither prevented the pipes from fracturing nor did they cause the fractures: Nos. 169, 584, 971, 1,011, 1,035, 1,056, 1,072, 1,109, 1,172, 1,185, 1,214, 1,264, 1,398, 1,461, 1,515, 1,537, 1,556, 1,747, 1,771, 1,899, 2,006. About half of these cases occurred on steamers.

The labour expended on this enquiry should afford a better insight than was previously possible into the question of endurance of steam pipes, and will, it is hoped, also lead to measurements being taken of the movements of engines and boilers, both when getting up steam, when running under ordinary conditions, and when encountering heavy weather

INSTITUTE OF MARINE ENGINEERS.

Visit to Works of Messrs. Siemens Bros. & Co., Ltd.

On Saturday afternoon, April 4th, a party from the Institute of Marine Engineers paid a visit to the Woolwich works of Messrs. Siemens Bros. & Co., Ltd. Established in 1864, these works cover an area of about 15 acres. During the last few years very large additions have been made and the two new blocks of five-storey modern factory buildings form a conspicuous landmark. The window space occupies about 50 per cent. of the area of the side walls, steam heating is installed throughout, and protection against fire is provided by the automatic sprinkler system and fire-resisting doors. In the central building is prepared the raw rubber which forms the base of the manufactured goods produced for the insulation and waterproofing of wires and cables and for ebonite articles of all kinds for electrical apparatus. In the building on the south side are constructed the torsion meters, projectors, railway signalling apparatus, and electrical instruments. All the machinery is driven by electrical power generated at the power-house situated in the older portion of the works. The steam is raised by five Laird gunboat boilers and two Babcock & Wilcox boilers arranged for natural and induced draught. The generating plant comprises five 300 h.p. steam engines coupled direct to Siemens continuous-current shunt-wound dynamos, each having an output of 1,500 amperes and 120 volts, at 350 revs. per minute.

The manufacture of cables insulated with gutta-percha or india-rubber forms a large part of the operations of the company. The attention of the visitors, however, was directed more especially to the details of wireless telegraphy apparatus in course of construction, the company having in 1910 acquired the British rights of the Quenched Spark (Telefunken) system. In the wireless station and testing room a general description and demonstration of the system was given. In the aerial only one wave is generated, to which the whole of the energy can be applied. The frequency of the impulses producing the energy in the aerial being very high, a low electrical potential in the transmitting apparatus is necessary and a comparatively small apparatus may thus be used. As the distance between the plates of the spark gap is only ·2 mm., only a very slight hissing sound is heard, and no special sound-proof cabin is required. A 25 kw. naval station, the last of a set of five, was shown under construction. This is probably the largest station installed on a ship and has a guaranteed range of 1,000 miles by day and 2,000 by night. A representative 2 kw. set, as usually fitted on vessels of fair size, was shown, also ½ kw. and ¼ kw. sets. The latter, which is supplied to small vessels, yachts, &c., is extremely compact, the whole apparatus being contained in a cabinet 4ft. 8in. by 2ft. 2in. by 2ft. 2in. It has a range of 45 to 90 miles by day and 60 to 125 miles by night.

Some time was spent also in examining the details of the Hopkinson-Thring torsion meter for determining the horse-power transmitted by turbine and other shafts. The size of the instrument varies with the diameter of the shaft, but for a diameter of 12in. the over-all length is about 37in. The instrument consists of a collar clamped to the shaft of which

the torque has to be measured, and provided with a flange projecting at right angles to the shaft and an extension. A sleeve, provided with a similar flange and extension at one end, is clamped at its further end on to the shaft in such a manner that its flange is close to that of the collar, whilst its extension overlaps that of the collar on which it is supported to keep it concentric. Both the collar and the sleeve are quite rigid, and when the shaft is twisted by the transmission of power the flange on the sleeve moves relatively to that on the collar, this movement being equal to that on the portion of shaft on which the fittings are clamped. This movement is made visible by torque mirrors mounted between the two flanges, each reflecting a beam of light, projected from a lamp, on to a scale divided in a suitable manner on ground glass. The mirrors rotate with the shaft, but even at moderate speeds the reflections appear as continuous lines of light across the scale and there is therefore no difficulty in taking readings.

In the new machine shop, which was next visited, various ingenious electrical devices were examined. Among these was a tell-tale for engine revolution. This apparatus shows, by means of a flag indicator on the bridge or in any desired position, that the propellors are in motion, and the direction in which they are rotating, a definite indication being given for each revolution. A demonstration was also given of the company's loud-speaking marine telephones, the distinctive feature of which is that a very small current is used, thus obviating any trouble from the agglomeration of the carbon granules of the microphone. A machine for the automatic transmission of range-finding instructions and the method of operating the automatic telephone system were also demonstrated.

An adjournment was afterwards made to the offices, where tea was provided, and a vote of thanks, proposed by Mr. F. Crosby-Jones and seconded by Mr. F. O. Beckett, was accorded to the company and to the gentlemen under whose guidance the visit was made.

FULLAGAR'S TWO-STROKE CYCLE OIL ENGINE.

THE accompanying illustrations show a design of 2-stroke cycle oil engine, the invention of Mr. H. F. Fullagar, South Shore Road, Gateshead-on-Tyne. The engine is of the type comprising two units and embodying an air pump. In each unit of the engine A indicates the two engine cylinders each open at both ends and provided with the oppositely moving pistons B and C; D the crank shaft to which the pistons B are directly connected by rods; E and F the crossheads respectively of the pistons B and C; and G the external rods each directly connecting the piston B of one cylinder to the piston C of the adjacent cylinder through the corresponding crossheads E and F. The upper crossheads F constitute the movable member of a single-acting air pump, the other member of which is stationary. Each rectangular crosshead F moves in a tubular guide H, closed at the end remote from the crank shaft by a cover and forming an air pump chamber whose cross-sectional area may be twice, or more times, that of the main piston C to which it is attached, the stroke of both being, of course, the same. Each crosshead F and its guide chamber H thus forms an air pump capable of supplying one engine cylinder A with the desired quantity of air, whilst the original accurate balance of the engine is not disturbed. The air pumps are provided with the necessary inlet and outlet valves M and N respectively. These valves are automatic spring valves and are constituted by rectangular flat steel blades or plates, the inlet valves M controlling the inlet of air from an air inlet chamber P, and the outlet valves N controlling the delivery of air to the engine cylinders A through passages R in the walls of the guide or pump chambers H and ports S formed in the walls of the cylinders A between the inner ends of the pistons in the cylinders. The casing T surrounding and carrying each pair of engine cylinders is, as shown in Fig. 2, provided at opposite sides with inclined passages U through which and the guide casings H the pairs of cross diagonally arranged connecting rods G pass from the upper crossheads F to the lower ones E. In small engines, such as the one illustrated, the air is carburetted before it enters the air pump chamber, but in larger engines it may be desirable to inject the fuel separately either into the centre of the cylinder, in the case of liquid fuel, or through the air inlet ports S, or through separate suitably controlled gas ports.

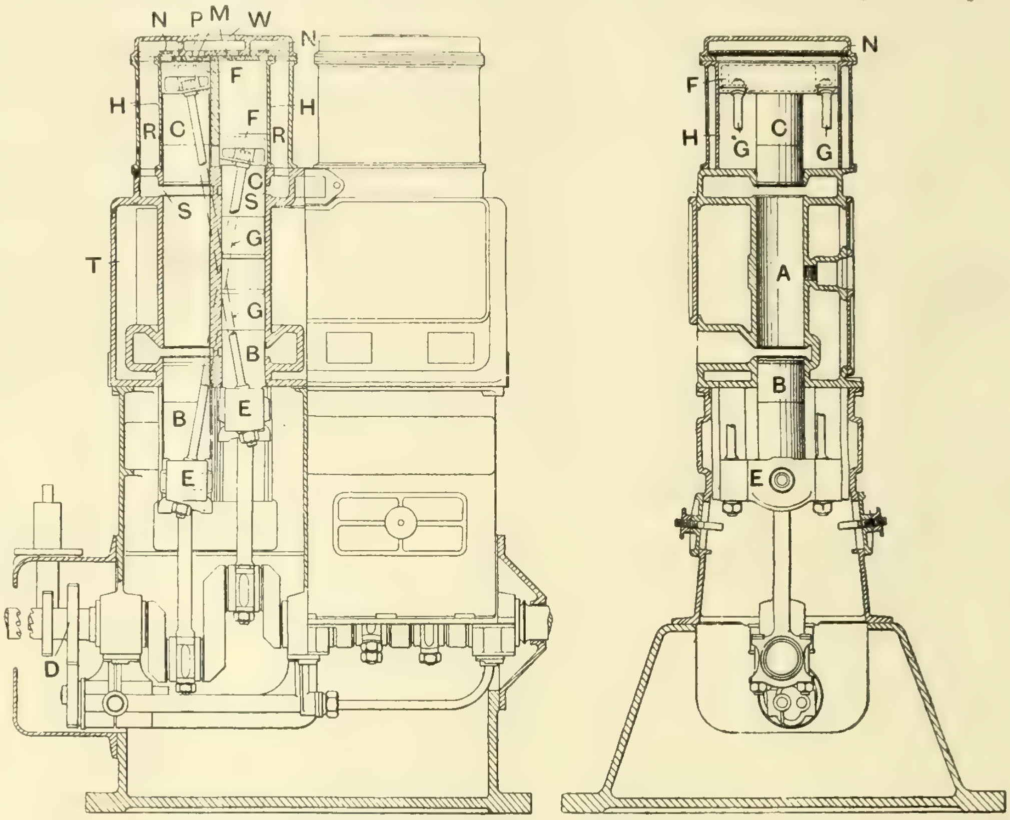


FIG. 1.—FULLAGAR'S TWO-STROKE CYCLE OIL ENGINE.

Management of Electric Motors.—In a paper by Mr. E. F. Butler on "The Operation and Maintenance of Electric Motors" recently read before the Junior Institution of Engineers, the author pointed out that as regards maintenance the object was to run the plant with as few stoppages as possible and without excessive cost. A frequent cause of trouble was that installations were put in without taking account of the working conditions and the class of people by whom the machinery was to be handled. To get the best results the upkeep of the plant should be considered before it was installed, and the points to which special attention should be paid were suitability to the requirements, accessibility, the use of the smallest possible number of different sizes of motors, and standardisation in every possible way, so that the number of spare parts and replacements which had to be kept in stock might be reduced to the utmost. In regard to the choice of motors and their control gear, the author enumerated the constructional features which should be found in a good machine and gave a series of practical hints for remedying faults in existing installations.

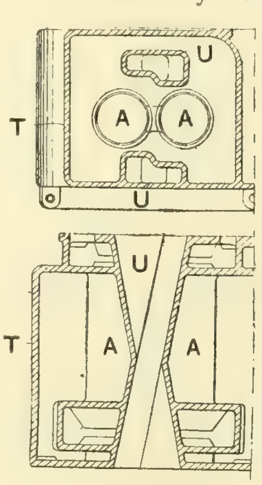


FIG. 2.

THE MICRO-CHEMISTRY OF CORROSION.*

Part II.—The α-Alloys of Copper and Zinc.

By Samuel Whyte, B.Sc., and Cecil H. Desch, D.Sc., Ph.D.

The experiments described by the authors in Part I. of this investigation† were confined to the β-solid solutions of the copper-zinc series, the original intention having been to examine the alloys of the Muntz metal class, containing both the α and β constituents. As the corrosion of such alloys begins always in the β areas, it was thought advisable to investigate the micro-chemical nature of the process in this constituent first, before proceeding to the more complex case. This selection had the disadvantage that the alloys examined were of little technical importance, and any results obtained from the experiments could not be directly employed to establish any practical conclusions. In this second part, the alloys dealt with are those which find the most important technical applications.

The use of an external electromotive force for the purpose of hastening corrosion undoubtedly introduces a factor which is not present in the ordinary conditions of unassisted chemical corrosion, but is unavoidable for the particular purpose which the authors have in view. Chemical corrosion is too slow and too irregular, too easily affected by accidental and uncontrollable changes in the conditions, to lend itself to investigation on the small scale in the laboratory for the purpose of obtaining quantitative data. Chemical corrosion is thus more satisfactorily studied by means of experiments on the large scale, continued over long periods, as in the elaborate series now in progress under the auspices of the Corrosion Committee of this Institute.

Nevertheless, it appears that experiments on a small scale may throw some light on the mechanism of corrosion, even when it takes place under conditions excluding the presence of an external electromotive force. The comparison of laboratory experiments with observations of corroded specimens of copper-zinc alloys from works and shipyards has convinced the authors that all corrosion of these alloys is preceded by dezincification, but that where the action proceeds slowly and there is free access of gaseous or dissolved oxygen, the spongy residue of copper may be converted into oxide as fast as it is formed. This, it is believed, is the origin of the adherent layer of copper oxide which is often found on the corroded surface of brass. The evidence for this view is given in the present paper.

The method of experiment employed was modified slightly in order to ensure greater accuracy, but was in all essentials the same as that described in the first paper. The cathode, instead of being a loop of platinum wire, was made of fine platinum gauze, 1 cm. square, having a vertical platinum wire welded to it for the purpose of attachment to a support. The Classen stand for electrolytic analysis was found to be most convenient for holding the cathode in place, the distance between the surface of the specimen and the cathode being adjusted by interposing a sheet of plate-glass 5 mm. thick, and bringing the cathode gauze into contact with it and then withdrawing the glass.

The analytical methods were the same as those described previously. Lead, which was not included in the earlier experiments, was removed from solution by electrolysis with a small platinum gauze anode, on which the lead was deposited as peroxide. This was then dissolved in a little nitric acid, evaporated to dryness, and dissolved in water. On the addition of 0·5 cub. cm. of a solution of hydrogen sulphide a yellow colouration was produced, which was compared in an Eggertz tube with that given under the same conditions by a standard solution of lead nitrate. No special difficulties were encountered in the course of the analytical work.

Record of Experiments.—In this series of experiments four alloys were used, one of which was examined in the annealed and also in the unannealed condition. The analyses are given in Table I. The figures in the last two columns give the composition of the equivalent copper-zinc alloys, determined by Guillet's method, the coefficients of equivalence of tin and lead being taken as 2 and 1 respectively.

Table I

Alloys.	Copper, per cent.	Zinc, per cent.	Tin, per cent.	Lead, per cent.	Fictitious Values by Guillet's Formula: Copper, per cent.	Zinc, per cent.
I. and II.	69·88	30·12		—	69·88	30·12
III.	69·89	29·03	1·08	—	69·15	30·85
IV.	70·15	28·85	—	1·00	70·15	29·85
V.	69·90	28·11	—	1·99	69·90	30·10

The "fictitious values" for zinc and copper represent the composition of the pure copper-zinc alloy which would correspond most closely with the actual ternary alloy. In the first series of experiments the application of the current was continued for 5 mins., the products being analysed immediately afterwards. Alloys I. and II. contain copper and zinc only, I. being unannealed and II. annealed at 800° C. for 2 hours, whilst III. contains tin and IV. and V. contain lead. The results of these tests are shown in Tables II., III., and IV. By "precipitate" is meant the flocculent precipitate of basic salts which appears in the electrolyte, and is readily separated from the specimen, whilst "adherent layer" denotes the metallic deposit which was mixed with zinc oxychloride in the cases of Alloys I., II., IV., and V., and with tin oxychloride in the cases of Alloy III. This deposit could not be flaked off as with the "β" alloys, this being probably due to the increased amount of basic salts which seemed to be intimately mixed with the coppery deposit from the surface to its junction with the brass beneath. If these basic salts were removed by a very dilute solution of hydrochloric acid (one drop in 30 cub. cm. of water) there remained an adherent layer of coppery crystals. This layer was much more difficult to detach from the brass than that which was produced in the corrosion of the β alloys, but, as in the former experiments, a perfectly sharp boundary between the brass and the

Table II.—*Composition of Precipitate.*

Time, 5 minutes.

Alloy.	Copper, Mgms.	Zinc, Mgms.	Tin, Mgms.	Lead, Mgms.	Total, Mgms.	Copper, per cent.	Zinc, per cent.	Tin, per cent.	Lead, per cent.
I.	0·90	0·95	—		1·85	48·6	51·4	—	—
	0·95	1·00	—		1·95	48·7	51·3		
II.	1·05	0·95	—	—	2·00	52·5	47·5	—	—
	1·00	0·91	—	—	1·91	52·3	47·7		
III.	0·30	1·22	none	—	1·52	19·7	80·3	—	—
	0·32	1·08	none	—	1·40	22·8	77·2	—	—
IV.	1·25	1·26	—	none	2·51	49·7	50·3	—	—
	1·20	1·07	—	none	2·27	52·8	47·2	—	—
V.	0·60	0·60	—	none	1·20	50·0	50·0	—	—
	0·60	0·57	—	none	1·17	51·3	48·7	—	—

Table III.—*Composition of Adherent Layer.*

Time, 5 minutes.

Alloy.	Copper, Mgms.	Zinc, Mgms.	Tin, Mgms.	Lead, Mgms.	Total, Mgms.	Copper, per cent.	Zinc, per cent.	Tin, per cent.	Lead, per cent.
I.	0·425	0·331	—		0·756	56·2	43·8	—	
	0·45	0·315	—	—	0·765	58·8	41·2		
II.	0·40	0·25	—	—	0·65	61·6	38·4	—	—
	0·375	0·20	—	—	0·575	65·2	34·8	—	—
III.	2·35	0·13	0·03	—	2·51	93·6	5·2	1·2	
	2·40	0·31	0·03	—	2·74	87·6	11·3	1·1	
IV.	0·80	0·13	—	none	0·93	86·0	14·0	—	
	0·83	0·20	—	none	1·03	80·6	19·4	—	—
V.	0·86	0·24		none	1·10	78·1	21·9	—	
	0·86	0·25	—	none	1·11	77·4	22·6		

Table IV.—*Total Weight of Corrosion Product.*

Time, 5 minutes.

Alloy I. .... 2·62 and 2·71 milligrammes.
,, II. .... 2·65 ,, 2·49 ,,
,, III. .... 4·03 ,, 4·14 ,,
,, IV. .... 3·44 ,, 3·30 ,,
,, V. .... 2·30 ,, 2·28 ,,

* Paper read before the Institute of Metals, March 18th, 1914.

† "Journal of the Institute of Metals," No. 2, 1913, Vol. X., page 303.

dezincified layer was always present. In the second series of experiments 100 cub. cm. of the electrolyte were allowed to flow over the surface during a period of 60 mins. (Tables V., VI., and VII.) The total weight of the corrosion product, including both the precipitate and the adherent layer, is given in Tables IV. (5 – min. tests) and VII. (60-min. tests).

Microscopical Observations.— The Alloy I., containing copper and zinc only, had a very distinctly cored structure when examined in the cast condition, the appearance under the microscope being characteristic of an α-solid solution in a state of imperfect equilibrium. Annealing for 2 hours at 800° rendered the alloy perfectly homogeneous. A specimen was also examined in this state, and appears in the tables as Alloy II. Alloy III., containing tin (1·08 per cent.), was also heterogeneous in the cast condition, showing distinct segregation of the copper-tin constituent at the boundaries of the crystals. This constituent disappeared on annealing, and this and the remaining alloys were only employed for the corrosion tests in the annealed condition. Alloy IV. did not become completely homogeneous on annealing, but small salts, which adhered very firmly, and, having a dull surface with low reflecting power, made it difficult to obtain satisfactory photographs. Momentary immersion in very dilute hydrochloric acid removed the greater part of the oxychloride, exposing the coppery layer, which was invariably made up of small crystals, mainly exhibiting octahedral angles. In the long-period tests etch-figures were conspicuously developed, cubic forms being frequently observed. Fig. 1, taken from Alloy I., shows this effect, the cubic angles being well seen surrounding a rather deep etching-pit on the left. Fig. 2, taken from Alloy III., shows the general appearance of the surface after detaching the film of copper. The crystal boundaries have been revealed by the corrosion, and the difference of orientation in neighbouring grains is perceptible, but is somewhat less conspicuous than in the β alloys under similar conditions. The black area in this photograph represents a firmly adherent layer of oxychlorides, covering one or more crystal grains. The cored structure of the unannealed specimen, Alloy I., was strongly developed during corrosion, finally leaving ridges in high relief, whilst the annealed alloys

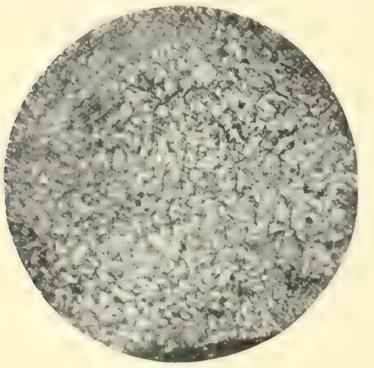


FIG. 1.—ALLOY I. 1-HOUR TEST. ETCH FIGURES. MAGNIFIED 200 DIAMETERS.

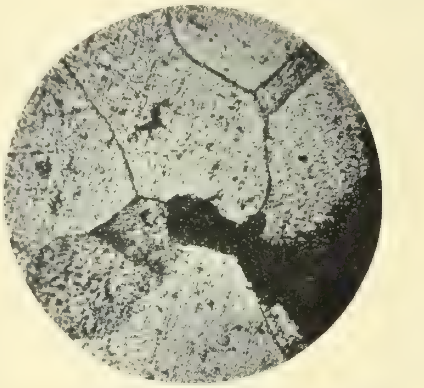


FIG. 2.—ALLOY III. COPPERY LAYER REMOVED. MAGNIFIED 45 DIAMETERS.

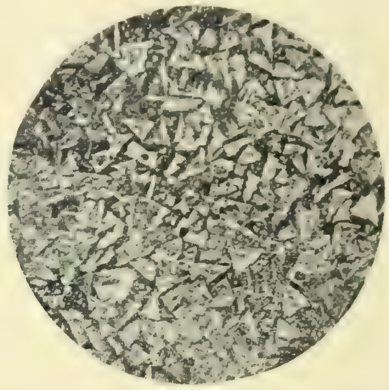


FIG. 3.—ALLOY V. ETCH FIGURES. MAGNIFIED 200 DIAMETERS.

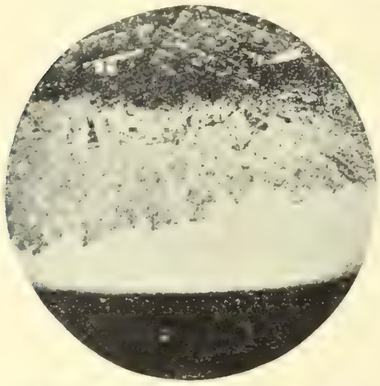


FIG. 4.—SECTION OF CORRODED CONDENSER TUBE. MAGNIFIED 20 DIAMETERS.

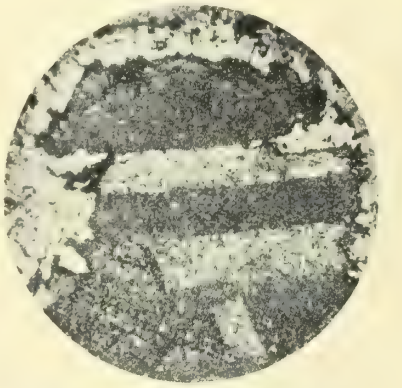


FIG. 5.—CORROSION ALONG BOUNDARIES AND TWINNING PLANES. MAGNIFIED 160 DIAMETERS.

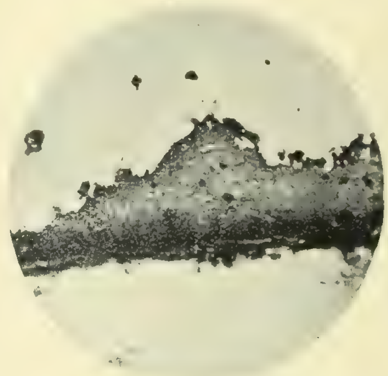


FIG. 6.—ARTIFICIAL CORROSION OF CONDENSER TUBE. MAGNIFIED 30 DIAMETERS.

isolated areas of lead remained undissolved here and there, whilst Alloy V., with twice the quantity of lead, showed well-defined bands of segregated lead at the boundaries of many of the crystals.

The behaviour of the alloys on corrosion was characteristic, and strikingly different from that of the β alloys. This was specially noticeable in regard to the film of copper left after dezincification. This was always intimately mixed with basic corroded very uniformly. The effect of lead was remarkable. On clearing off the adherent layer from Alloys IV. and V.

TABLE V.—*Composition of Precipitate.*
Time, 60 minutes.

Alloy.	Copper, Mgms.	Zinc, Mgms.	Tin, Mgms.	Lead, Mgms.	Total, Mgms.	Copper, per cent.	Zinc, per cent.	Tin, per cent.	Lead, per cent.
I.	8·00	5·67	—	—	13·67	58·5	41·5	—	—
	8·00	5·60	—	—	13·60	58·8	41·2	—	—
II.	8·50	5·35	—	—	13·85	61·3	38·7	—	—
	8·40	5·30	—	—	13·70	61·3	38·7	—	—
III.	1·20	7·18	Trace	—	8·38	14·3	85·7	—	—
	1·20	7·68	Trace	—	8·88	13·5	86·5	—	—
IV.	6·00	4·54	—	none	10·54	56·9	43·1	—	—
	6·20	4·60	—	none	10·80	57·4	42·6	—	—
V.	5·00	4·09	—	none	9·09	55·0	45·0	—	—
	5·04	4·09	—	none	9·13	55·2	44·8	—	—

TABLE VI.—*Composition of Adherent Layer.*
Time, 60 mintues.

Alloy.	Copper, Mgms.	Zinc, Mgms.	Tin, Mgms.	Lead, Mgms.	Total, Mgms.	Copper, per cent.	Zinc, per cent.	Tin, per cent.	Lead, per cent.
I.	6·55	1·73	—	—	8·28	79·1	20·9	—	—
	6·45	1·60	—	—	8·05	80·1	19·9	—	—
II.	5·45	1·57	—	—	7·02	77·6	22·4	—	—
	5·35	1·58	—	—	6·93	77·2	22·8	—	—
III.	13·00	1·41	0·165	—	14·57	89·2	9·7	1·1	—
	13·00	1·58	0·165	—	14·74	88·1	10·8	1·1	—
IV.	7·50	1·73	—	0·09	9·32	80·5	18·54	—	0·96
	7·25	1·35	—	0·09	8·69	83·5	15·5	—	1·0
V.	4·25	1·25	—	0·11	5·61	75·7	22·3	—	2·0
	4·00	0·95	—	0·11	5·06	79·1	18·8	—	2·1

TABLE VII.—*Total Weight of Corrosion Product.*
Time, 60 minutes.

Alloy		
Alloy I.	21·95 and 21·65	milligrammes.
,, II.	20·87 ,, 20·63	,,
,, III.	22·95 ,, 23·62	,,
,, IV.	19·86 ,, 19·49	,,
,, V.	14·75 ,, 14·19	,,

each isolated mass of lead was seen to be surrounded by a ring of copper. Octahedral etch-figures were strongly developed, as is shown in Fig. 3.

The Relation Between Natural and Electrically Stimulated Corrosion.—An opportunity of comparing the effects produced by the application of an external electromotive force to an α brass in contact with salt solution with those observed in the corrosion of a similar brass under conditions of service was afforded by the examination of some condenser tubes. These tubes had been taken from a vessel on the Manchester Ship Canal, and exhibited in parts, especially near to the inlet end, very considerable dezincification, extending over the whole internal surface of the tube, but penetrating completely through the tube along a horizontal strip, occupying about one-quarter of the circumference, and forming the bottom of the tube. Along this strip the zinc had been completely removed, a transverse section showing nothing but somewhat spongy copper. The upper part of the tube, in the same section of its length, was dezincified to a small depth, becoming deeper in the lower part, and merging into the completely dezincified area.

A transverse section of one of the typically corroded portions was prepared, the tube being previously filled with fusible metal, in order to prevent any cracking or separation of the coppery layer during sawing. Fig. 4 is a section of a part of the tube where dezincification has extended half-way through the thickness of the metal. The section has been slightly heat-tinted, so as to darken the copper, leaving the uncorroded brass quite bright. The boundary between the two is irregular, but perfectly sharp.

Further insight into the mechanism of the process is afforded by an examination under a higher magnification, after etching with ammonia. Fig. 5 shows an area at the boundary of the corroded and the unchanged portions after being treated in this way. The light constituent visible at the circumference of the circle is porous copper, whilst the greater part of the area is α brass. Dezincification has proceeded, as usual, along the boundary of the crystal grain. As usual in annealed brasses, the α constituent shows repeated twinning, and it is interesting to observe that dezincification has invaded the mass of the crystal grain along a twinning plane. This behaviour is characteristic of the α brasses, and is observed throughout in this and similar specimens, whether corroded naturally or under the influence of an applied electromotive force. It indicates an electrochemical difference at a twinning plane, an effect which, although not often observed, is to be expected on theoretical grounds.

The attempt was next made to reproduce this corroded structure by using an applied electromotive force. A clean, uncorroded piece of the same tube was taken, cut to a length of 2 cm., and formed into a cell, containing the same electrolyte (5 per cent. sodium chloride solution) as that used throughout the experiments. The tube was the anode and a platinum wire was the cathode. After remaining connected with the cells for 24 hours the section of tube was washed, filled with fusible metal, sawn through, and polished. Dezincification was found to have taken place to a considerable depth. The effect is shown in Fig. 6, the structure having been developed by heat-tinting. As before, the boundary between spongy copper and brass is a very sharp one, and is found, on examination under a higher magnification, to follow the outline of the crystal grains, penetrating into them along the twinning planes. There is thus complete identity between the corroded structure which was produced under working conditions in contact with the water of the Manchester Ship Canal and that obtained artificially, using salt solution and an external electromotive force.

The composition of the condenser tube was somewhat unusual, the proportion of zinc being considerably below that of a normal 70 : 30 brass. Several concordant analyses gave as the composition:—

	Per cent.
Copper	72·72
Zinc	27·04
Iron	0·15
Lead	0·09
	100·00

There is no reason to suppose that this difference in the percentage of zinc makes any appreciable difference in the process of corrosion.

Discussion of Results.—The total corrosion of the α alloys is, as might be expected, much less than that of the β alloys under the same conditions. A relatively much larger proportion of copper is also removed in solution, that is, there is less preferential removal of zinc than in the case of the β alloys. This also is in accordance with expectations, the α-solid solution having less tendency to lose zinc than the more concentrated β solution.

There is very little difference between the resisting powers of the unannealed and annealed alloys of copper and zinc (I. and II.), but such small differences as occur are uniformly in the direction of lessened corrosion after annealing. Of the remaining alloys, the greatest amount of corrosion is given by that containing tin, and the least by that containing 2 per cent. of lead.

It must be repeated that this method determines only the initial stages of the process of corrosion, and the results must be interpreted from this point of view. The physical character of the process is as important as its chemical nature, since the physical properties of the deposit formed on the surface of the metal determine whether subsequent corrosion will proceed with constant or accelerated velocity, or will be gradually brought to a standstill.

Taking Alloy II. as a standard of comparison, it is seen that Alloy I., the structure of which is less homogeneous owing to the presence of cores, corrodes to a slightly greater extent, the removal of zinc taking place principally at the periphery of the crystallites. Dezincification proceeds here to a greater extent, but there is no important difference in the physical properties of the adherent layer in the two cases.

Alloy III., containing tin, is corroded much more rapidly at first than Alloy II. In the 5-min. tests this difference is very marked, but it becomes less in the 60-min. tests, and there is little doubt that it would disappear and even be reversed in tests continued over longer periods. This is due to the formation of a remarkably tough layer of basic salts. Dezincification proceeds far, but the coppery layer, instead of being easily detachable, is firmly cemented to a compact mass by basic salts, the tin being retained in this deposit. Such a layer must offer a considerable obstacle to further corrosion. This effect was also observed in the experiments with β alloys.

Alloy IV., containing 1 per cent. of lead, also shows dezincification, but the adherent layer, unlike that of the tin alloy, is loose and open in texture. It is therefore not surprising that the total corrosion is not lessened appreciably; in fact, the 5-min. tests show an increase.

Alloy V., containing 2 per cent. of lead, is dezincified locally, the areas of free lead becoming surrounded by a zone of copper, which gradually extends over the entire surface as the process is continued. The coppery layer is very firmly adherent. In its upper portions it is cemented by basic salts, but a layer of copper, containing comparatively little zinc, intervenes between this varnish-like layer and the unchanged metal. The total corrosion is less than that of any of the other alloys, and the advantage becomes more pronounced as the time of testing is extended, being greater in the 60-min. than in the 5-min. tests.

The experiments have confirmed the authors in their opinion that there is no essential difference between the processes of electrically stimulated and natural corrosion, and that consequently the method that they have described may be employed for the purpose of determining the probable order of resistance of alloys to corrosion. The results now presented are in good agreement with the conclusions of Dr. Bengough's report as to the suitability of different alloys of the α series. It is next proposed to examine the influence of other added metals on the α alloys, and also the behaviour of the α, β, or Muntz metal alloys.

Institute of Metals: Birmingham Section.—At a meeting of the Birmingham Section of the Institute of Metals, under the presidency of Prof. Turner, a paper by Messrs. Shepherd and Merrick on "Non-ferrous Metals" was read. The defects shown in numerous arrays of samples were explained. There were upwards of 40 different samples, ranging from a copper billet containing blowholes to naval brass condenser tubes designed to meet Admiralty mechanical tests.

BLASTFURNACE GAS CLEANING PLANT.

IN the course of a paper on the cleaning of blastfurnace gas read by Mr. A. N. Diehl at the February meeting of the American Institute of Mining Engineers, a brief abstract of which was given in our issue of April 3rd (see page 316 ante), the author discussed the method of handling the flue dust problem at the Duquesne works of the Carnegie Steel Company as follows:—

The amount of moisture in the raw gas varies with the water in the stock. The use of Mesabi ore has made the addition of water a necessity in most hard-driven furnaces in order to prevent dust being blown over, and this water, of course, is evaporated and carried by the gas. Per pound of

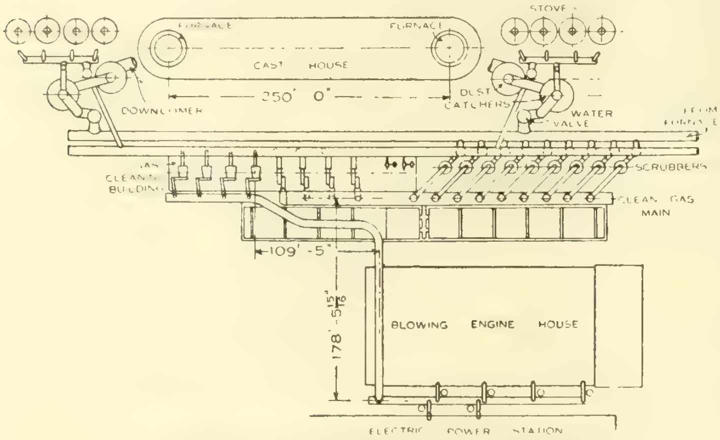


FIG. 1.—GENERAL ARRANGEMENT OF GAS CLEANING PLANT.

dry fuel gas consumed, clean gas with moisture saturated at 70° Fah. gives an available heat of 79·51 per cent. if the products of combustion are cooled to 600° Fah. Raw gas at 400° and 35 grains moisture has an available heat of 77·03 per cent. Partly-washed and cooled gas at 125° Fah. gives an available heat supply of 74·33 per cent. From a calculated thermal standpoint, we conclude that washed gas cooled to 70° Fah. gives the largest percentage of available heat. This is followed by hot unwashed gas under furnace-top conditions carrying 35 grains moisture. The lowest percentage of available heat exists for washed gas cooled to 125°. It is interesting to note that thermal equilibrium between raw unwashed gas and washed gas approximates a temperature midway between 70° and 125°.

The solids contained in the gas consist of the mechanically carried particles of varying degrees of fineness and a volatile substance which is carried as a gas and finally deposited, or which may pass through the entire system. The gas from the furnace should deposit the heavier material of the flue dust in the dust catcher and pockets, and only the lighter material should pass to the scrubbers. In order to determine if this is true, we took samples of the dust from the dust catcher at the Duquesne plant and also samples of the sludges from the settling basins. We first endeavoured to sieve the material, after drying, but with no success, and then washed it through screens, weighing that which remained. The screens ran up to 300-mesh, and the tests show that 92 to 95 per cent. of the sludge from the basin passed through the 300-mesh screen. This material is also the richest in metallic yield, showing 41 per cent. iron. It is noticeable that only about 18 per cent. of the fine dust remained in the dust catcher. This may have been carried down in contact with larger particles; that is, the fine particles would stick on the larger ones, but would be separated by water. Very interesting data would be revealed if ore were wet sieved instead of dry sieved; a more uniform and more accurate representation of the actual physical condition would then be had. An ore which we sieved dry ran 9 per cent. through 100-mesh, and the same sample ran 24 per cent. through 100-mesh when wet sieved.

Bearing in mind the finely divided condition of the dust, as shown in the sieve tests, it will be interesting to note the rate of settling of this material. We have a double settling basin. The water passes from the collecting sewer beneath the scrubbers and flows into one section, filling it with dirt. The dirty water is then diverted to the other section, and the first cleaned by means of a grab bucket, the material being loaded into cars. There are six partitions, or baffles, which tend to hold back the dirt and aid in settling it. Each division of the basin is 161ft. long and 26ft. wide, the water flowing over a weir at the end. The capacity is 500 tons of wet dirt. Each side of the settling basin holds 197,920 galls. of water when clear of dirt. The dirty water was allowed to flow through for a day; then, from a platform erected over the first compartment, samples were taken at various depths. A brass tube fitted with a rubber stopper and a rod was used to obtain the samples. The closed tube was lowered to the desired depth, the bottom opened and the water allowed to flow in. The stopper was then drawn into place and the samples put in a jar for weighing and measuring.

The sludge in the settling basin is of the consistency of a thick jelly and filters with almost the same rapidity. In this condition it is extremely difficult to handle. We allow the basin to drain as much as possible, then remove the sludge with a grab bucket, and load into cars. These cars must be caulked water tight to hold the material. If the material would drain easily most of the trouble would be obviated, and tests were made to locate the difficulty. A flume was first constructed to carry the water from one scrubber and with sufficient fall to create fairly rapid flow. Constrictions were built in the flume so as to speed up the water at different points to carry the lighter material forward. By this scheme we succeeded in making a rough separation, and obtained a fine but granular product from which the water drained easily. The trough was widened out somewhat at the end and the speed of flow decreased. This gave us the same product we had to deal with in the basins, as a lot of fine material was deposited. In order to determine a settling standard for comparison, we took some Group-3 ore, a standard Mesabi, and wet sieved it through the various screens up to 300-mesh. These different screenings were put into similar bottles filled with water and shaken up. The material which passed through the 200-mesh sieve took 14 seconds to settle; that which passed through the 300-mesh required several hours. A scum of fine, light material, principally coke dust, extremely gelatinous, forms on top of the basins and afterward sinks. Mixing a small quantity of this material with the coarse dirt which previously filtered freely, at once prevents all filtration. It is reasonable to suppose that a lot of the dirt could easily be handled if this slime were eliminated. We are at present experimenting with various means to make this separation and expect to do away with many of the difficulties in

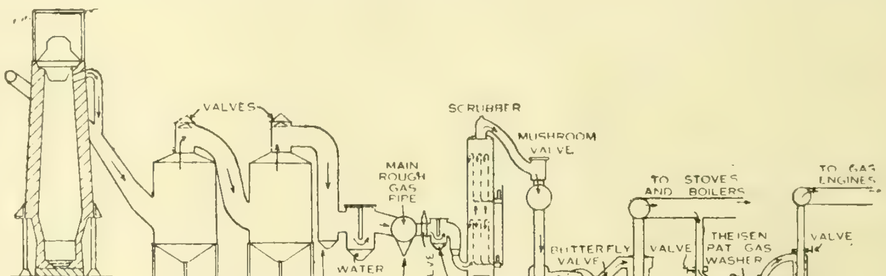


FIG. 2. COURSE OF THE GAS THROUGH THE CLEANING PROCESS.

handling this material and also recover a good product for sintering or charging back.

An attempt was made to arrive at a correct figure for dirt in the gas entering the scrubbers, and it was decided that 500 cubic centimetre samples of water should be taken at intervals from the overflow water of the scrubber and collected in a carboy. The water was afterwards filtered. In this manner, and over a period of 19 days, samples consisting of 2,000lbs. each were taken. From weir readings on the settling-basin overflow, we determined the quantity of water for the period, and by means of recording meters and Pitot-tube readings we determined the gas volume passing through the scrubbers, and, therefore, determined the actual dirt represented in 6,240 cub. ft. of gas, which was 2·6 grains per

cubic foot. The sampling was done under normal operating conditions.

This dust consists of ore, coke dust, and limestone dust, beside organic acids and compounds which seem to condense and are composed principally of silica and alumina. The gas may be of a dense white nature, or of a reddish hue, due to the predominance of fume in the former case, and ore dust

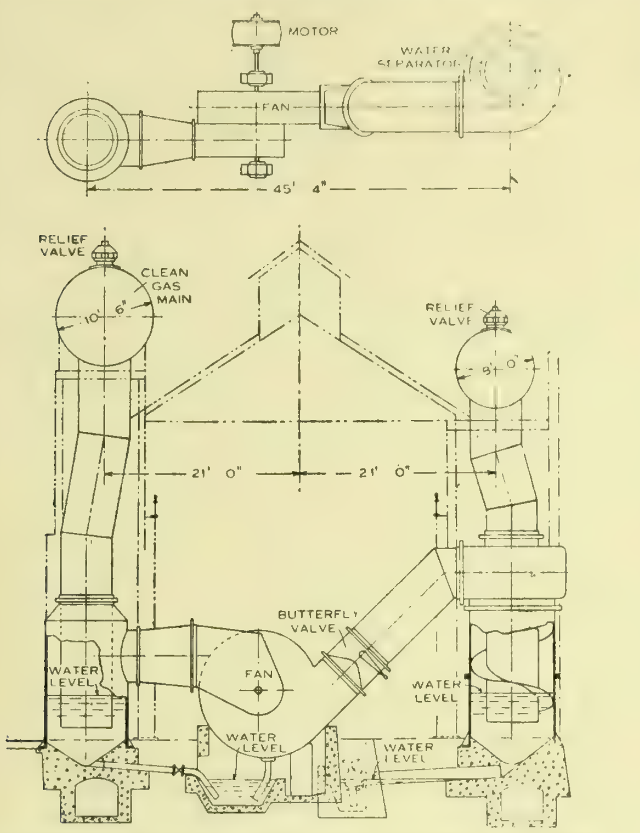


FIG. 3. SECTION THROUGH THEISEN WASHER, SEALS AND SEPARATORS.

in the latter case. The former is the harder to remove, and almost invariably if the dirt on the filter capsule in the testing apparatus is light in colour, the gas is dirtier than if red. Gas after final cleaning still retains some of the whitish fume. This material is deposited in the bottom of the stoves, in the stacks, and on the boiler settings. In places where the gas has only been rough cleaned the colour is a pinkish white, without grit and with a feeling similar to talcum powder. The stacks at all times show this white fume, and a determination was made to see how much of the dust left in the gas at the scrubbers passed through the entire system without depositing. It indicated that 27·5 per cent. of the dirt shown in the scrubber analysis passes through the entire system.

The system of cleaning gas at the Duquesne blastfurnaces consists at present of scrubbers, fans, and Theisen washers. This installation was first designed for the purpose of cleaning gas for six 3,600 h.p. gas engines, four sets of stoves, and 1,500 boiler horse-power. At the time of its installation it was the largest in the country and very little reliable data could then be collected on the subject. Nine towers, four fans, and four Theisen washers were erected. After operating a while, numerous changes became necessary. We found that four scrubbers, two fans, and two Theisens were sufficient for the demands. The plant is shown in the illustrations as at present.

We first started with scrubbers having a rotating nozzle at the top, the water to form a rain and thus come in contact with the gas and clean as well as cool it in this manner. The gas channeled under these conditions; the pressure over the scrubber area was constant, but the ascending gas column, due to velocity head, deflected the water. This was shown clearly by repeated tests, using a pipe with a funnel on one end and a standard pail outside, the time required to fill the bucket being taken. After the bucket was full, the pipe was withdrawn 4in. and the filling timed once more. In this way we tested across the scrubber. Distinct dry areas were found, irrespective of all possible regulation of water and gas deflecting apparatus.

It was then decided to reverse the scheme of having gas the dominating element and put in the water in such manner as to change the direction of the gas in its upward course and at the same time spray it repeatedly. This was done by injecting the water through a valve having a number of openings and a core moving therein. This core successively blocks off the openings to the different nozzles, and thereby temporarily stops the flow of water, causing an area of low pressure directly above the nozzle. When the core has passed, the water resumes and sprays through the gas which has flowed to this point, driving it to the next nozzle, where the same process is repeated. The core is revolved electrically, a 5 h.p. motor being ample for the four valves on two scrubbers. The gas rises through the scrubber at the rate of 4ft. per second and the water at 60ft. per second with a head of 35lbs. main pressure. A second valve is placed in the scrubber just above the range of the lower one and operates in the same manner. Screens are placed above the nozzle to break the water up into fine drops so as to bring the gas and water into intimate contact. It is evident that the gas will be repeatedly sprayed as it travels in an upward spiral course until it has passed the range of the water. Fifteen revolutions per minute is found to be about the right speed for the core. Fig. 4 is a section through the scrubbers.

The gas is cooled down very effectually, numerous readings showing only 5° to 6° above the temperature of the ingoing water. An average moisture test shows 0·5 grain above the saturation point at the temperature of the outgoing gas. These tests were taken on the outlet pipe of the scrubbers and were made with the Brady apparatus and also with the Brown apparatus. The difference in temperature between the gas and water can be increased or decreased, depending on the quantity of gas passing through the scrubbers. We have found that between 25,000 cub. ft. and 30,000 cub. ft. can be passed through our 12ft. scrubbers. The moisture content of the gas increases very rapidly above 90° Fah., and we aim to keep under this as much as possible. The moisture, if not controlled within limits, will lower the stove efficiency to such an extent as to make cleaning prohibitive.

The water is taken from the service mains and is charged at the regular water rate. This condition is different in

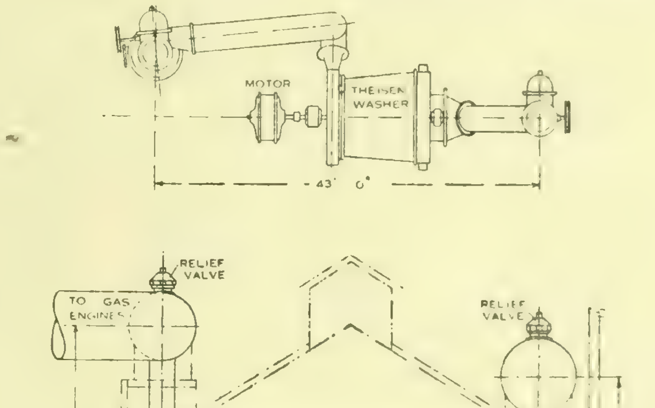


FIG. 4. SECTION THROUGH SCRUBBERS SHOWING APPARATUS FOR PRIMARY CLEANING.

plants where waste water is used. The Duquesne plant construction is such as to deliver our bosh cooling water to mill condensers and water-purification plants. About 815 galls. of water are used per minute per scrubber. All water flows over a weir, so that the quantities are accurately determined,

readings being taken four times a day. The electric power is metered, and the quantity of gas delivered to the engines is determined by Venturi recording instruments. The stove gas is determined by Pitot-tube readings, hydro-determinator and Ellison gauge, all results checking closely. The water used in gas valves and seals flows to the settling basins and is, therefore, recorded in the weir readings.

The fans are of Sturtevant type, electrically driven by direct and alternating-current motors; each one has a capacity of 84,000 cub. ft. of gas per minute. A water seal is placed on either side to provide means for repairing. The seal after the fan also forms a spiral separator for water which may be picked up in the fan. A caulked main serves to connect the scrubbers with the fans and is 10ft. 6in. diam. After leaving the fans, the gas is carried into an 8ft. primary gas main and distributed.

The Theisens are four in number, three being driven by alternating and one by direct-current motors. The motors are each 150 h.p. and drive the rotor 375 revs. per minute. Each Theisen has a capacity of 15,000 cub.ft. of gas per minute. There are seals and separators on the Theisens the same as on the fans.

The gas from six blastfurnaces is allowed to go into a general dirty-gas main, 8ft. 6in. diam., and is distributed to the boiler-houses, both sets of stoves and gas-cleaning plants. A pressure of 12in. of water is maintained in this main. The gas for the gas cleaning plant goes through water valves to the scrubbers which are in parallel, and thence to the 10ft. 6in. collecting main, from which it goes through the fans to the primary or scrubbed-gas main and is distributed to No. 3 boiler-house extension to stoves on Nos. 3, 4, 5, and 6 furnaces, and to the Theisens. The pressure in the receiving main is 10½in. and in the primary main 8in. The Theisens boost the pressure to 12in. and deliver the gas to the engines. These pressures relate to operation without fans, the gas being propelled by the pressure of the furnace. We operated for a period of a year and a half this way, but are using fans now, due to a desire to lower the top pressure, saving gas losses, and lessening the dangers during tuyere changing, &c., when a high gas-main pressure causes trouble. We desire a pressure of 5in. to 6in. at the stove burners, for the reason that our distributing mains are too small and we have poor stove draught. The friction through the various fan seals, and through the fans, also made it necessary to back up the gas. In a new installation many of these difficulties would be obviated. Formerly we removed no dirt in the fans, but we have so altered them lately as to reduce the dirt content from 0·2 to 0·06 grain per cubic foot. The Theisen washers, as shown in the gas test for 1912, lower the dirt content to 0·009 grain per cubic foot.

TURBO-ALTERNATORS.

BY R. B. WILLIAMSON.

THE design of alternating-current generators for connection to steam turbines involves a number of requirements that are not difficult to comply with in ordinary slow or moderate speed generators, but which become serious problems in machines operating at the excessively high speed required for this type of generator. For example, the windage loss becomes relatively very large, and all the magnetic and electric losses are concentrated within such small space that special care must be taken to secure adequate ventilation. Other problems are encountered in the design of the winding that are quite easily handled in an ordinary slow-speed machine, but which require special treatment in a turbo-alternator.

For a given output there is a speed at or near which the most economical design, taking everything into consideration, can be obtained. Theoretically, turbo-alternators should be cheap machines per kilowatt output, because they run at high speed; as a matter of fact, slower-speed water-wheel generators can frequently be built at lower cost per kilowatt. This is because the turbo-generator operates at such excessively high speed that expensive material must be used, and the design is so limited in other respects that the total cost works out high. Thus it may cost no more to build a 3,000 kw. water-wheel alternator running at 300 or 400 revs. per minute than a turbo-generator of the same output running at 3,600 revs. per minute. Generally speaking, the most economical design for machines of fairly large outputs is obtained with peripheral speeds ranging from 7,000ft. to 10,000ft. per minute, and practically all turbo-generators must of necessity operate at peripheral speeds much beyond these values. It follows, therefore, that it does not pay to run the peripheral speed of this type of generator any higher than is needed to secure a suitable design in other respects.

Many of the earlier machines were designed for peripheral speeds much higher than necessary, with the result that the centrifugal forces in the rotor were hard to take care of, and, what was perhaps a greater drawback, the windage and friction were so high as to result in poor efficiency, particularly at fractional loads. Moreover, the large windage and friction loss produced considerable initial heating in the generator. High peripheral speed gives a rotor of relatively large diameter, which, for a specified output, makes the revolving part comparatively short as measured axially. A few years ago both of these features were considered desirable by designers because the short machine was more easily ventilated, and the distance between bearing centres was kept down so that there was no difficulty in making the critical speed of the rotor exceed the normal running speed. As the demand for still larger outputs increased, the designer was forced to make longer machines, because the peripheral speed

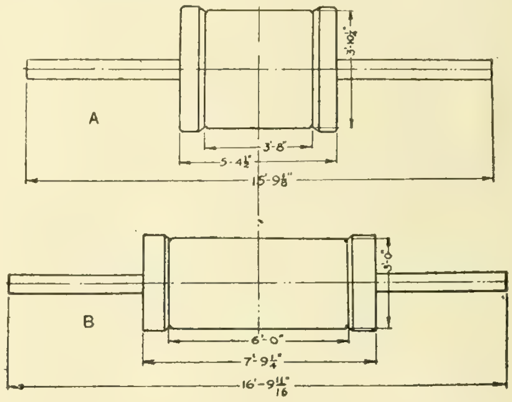


FIG. 1.

was already about as high as could be safely used, and larger diameters were not feasible.

These longer machines of large output brought up problems relating to ventilation that were successfully solved, so that in this respect there was no further difficulty in building machines of considerable axial length and keeping the temperature rise of the middle parts within safe bounds. It was also found that long machines could be run above their critical speed without trouble—that is, the rotor, in coming up to normal speed, passed through its critical speed, and no bad results from vibration were noticed. In fact, it has been found that rotors running above their critical speed are, if anything, easier to balance and run more smoothly than the short stiff rotors formerly considered most desirable. It was also found that these long machines of large output were more efficient than the shorter ones, principally because the windage loss was a smaller percentage of the output.

The next step, therefore, was to build machines on smaller diameters, where this could be done advantageously, with the result that a considerable improvement was made in efficiency, especially in generators of sizes ranging from 5,000 kw. down. Fig. 1 shows the relative sizes of two rotors, each for 5,000 kw. turbo-generators running at 1,800 revs. per minute. Rotor A is one of the earlier type, running at a peripheral speed of approximately 22,000ft. per minute; rotor B, of smaller diameter and greater active length, runs at a peripheral speed of 17,000ft. per minute. In Fig. 2 comparative efficiency curves are shown. On account of the much lower windage loss of the smaller diameter rotor, it is seen that there is a decided improvement in efficiency, especially at fractional load. It must be remembered that a gain of 1 or 2 per cent. in efficiency in a large turbo-generator unit represents a large net saving in the course of a year's operation.

The tendency in turbo-generator design is towards larger and larger units, machines of 25,000 kw. to 35,000 kw. now being installed or under construction. Such generators have stator cores of great length, and the problem of getting rid of the heat developed in the core and windings is a difficult one. Considering the heat developed in the copper conductors of the stator, this is not in itself a very large loss expressed as a percentage of the output, but most of these large machines are wound for rather high voltage (9,000 to 13,200 volts), and there is considerable thickness of insu-

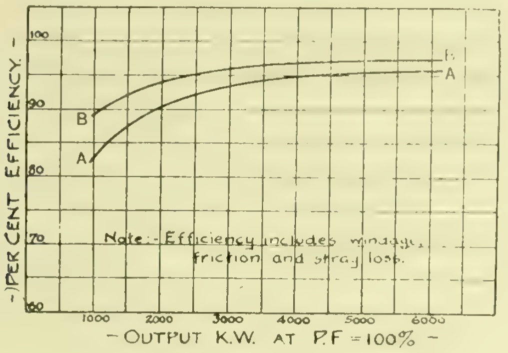


FIG. 2.

lating material surrounding the conductor. All insulating materials are poor heat conductors, and all the heat developed in the copper must find its way out through this covering. In turbo-generators the projecting ends of the coils are comparatively cool, but they cannot be depended on to act as radiators of the heat dissipated in the middle of the machine, where the core has considerable length measured axially. If we assume for a moment that all the heat in the conductors is disposed of by conduction to the ends, it can easily be shown that the difference in temperature between the centre of the core and the end necessary to cause this flow of heat is directly proportional to the square of the distance from the centre to the end. Thus this temperature difference increases very rapidly, and in long generators the heat-radiating effect of the coil ends cannot be depended on to any great extent. The heat developed in the copper must pass through the insulation to the iron, and sufficient surface must be provided for the passage of this heat so that the temperature difference between copper and iron will not become excessive. This means that the winding must be sub-divided and the current density in the conductors limited so that the number of watts per square inch area of insulation will not exceed the allowable amount.

In large turbo-generators the slots are of considerable radial depth, and as there are frequently but one or two conductors per slot these conductors are also deep. It is therefore necessary to take special precautions to minimise eddy currents induced in the conductors by the cross-flux in the slot set up by the working current in the conductor. Such deep conductors, if made of solid copper, would heat excessively, and must be stranded or laminated in such a manner that these currents would be partially or wholly neutralised. In some cases the conductor has been made of stranded cable pressed to shape or of flattened hollow cable. In other cases the conductor is made of parallel strands, and the parts of the coil inter-connected so that the eddy currents in one part will be partially neutralised by those induced in another part.

Another feature in large turbo-generators that calls for special attention is the bracing of the stator coils where they project beyond the core. These overhanging parts must be securely supported and braced against side motion, otherwise the conductors will be twisted or bent out of shape in case of short circuits on the generator. When a turbo-generator is suddenly short-circuited while running at full voltage an enormous current flows for an instant, and oil switches will not operate quickly enough to prevent this flow. The attractive or repulsive action between the conductors sets up very large forces between adjacent parts of the overhanging coils, with the result that they will be distorted if not securely braced. This is only another instance of one of the many things which become very prominent in a high speed turbo generator, but which give little or no trouble in slow-speed machines. At first this coil distortion gave considerable trouble, but methods of coil bracing have now been developed to such an extent that these generators will stand momentary short-circuits without damage. In the case, however, of large 25-cycle machines it is frequently advisable to install external reactance coils to limit the short-circuit current, and the use of these coils is now becoming very general in large stations. It must be remembered that even though the coil may not be damaged by a short circuit, very severe mechanical stresses are set up in the whole machine, and other troubles may be caused on the system by the excessive rush of current.

When one stops to consider that more power is now developed in a single-high-speed unit than was found only a few years ago in many stations of very respectable size, the advances made in this class of apparatus are remarkable, and the above is intended merely as a brief outline of some of the problems met with in this class of apparatus.—"Sibley Journal of Engineering."

APPARATUS FOR ASCERTAINING THE HARDNESS OF METALS

IT is a well-known workshop practice to test the degree of hardness of pieces of metal by means of a file held in the hand of the workman and rubbed across the pieces, the estimation being entirely dependent upon the operator's experience and judgment. To eliminate the personal element in making such tests as the foregoing, and to provide means for accurately comparing the bodies to be tested with a standard specimen, Messrs. Rudge-Whitworth, Ltd., Coventry, in conjunction with Mr. H. L. Heathcote, have designed and patented the apparatus shown in the accompanying cuts. It

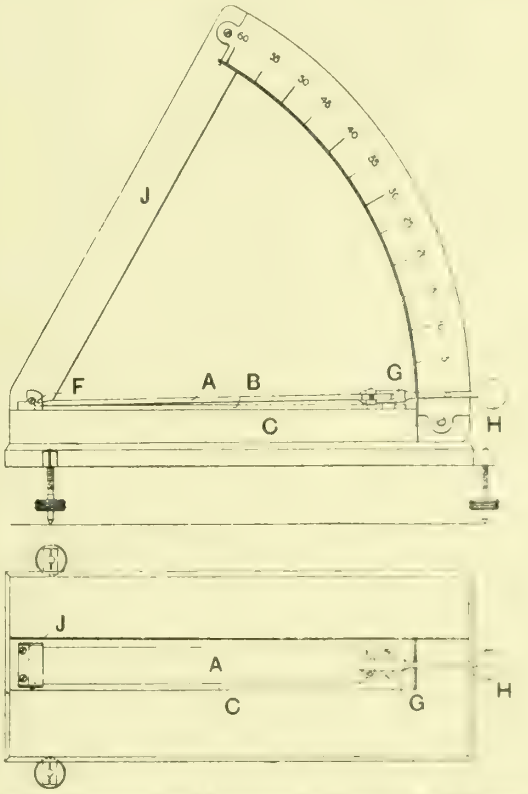


FIG. 1. APPARATUS FOR ASCERTAINING HARDNESS OF METALS.

has been observed that if a flat piece of metal be placed upon a horizontally positioned flat-topped piece of the same or another material, and the latter be tilted, then after a certain angular movement depending upon the friction between the surfaces, the upper piece will begin to slide, or, sliding, will continue to slide down the under piece. It has also been found that if one of the surfaces is hard and rough, *i.e.*, ridged or pointed, so as to cause abrasion, the friction and consequently the angle when movement just begins or continues depends upon the degree of hardness of the softer surface. For instance, if a piece of hard flat steel is placed upon a

horizontally positioned flat file and the file is tilted to the exact angle where the force of gravity overcomes the friction between the contact surfaces so that the metal begins to slide down the file, the angle is less than the angle when a similarly shaped piece of soft metal such as lead is employed instead of hard steel.

The apparatus shown in Fig. 1 has been designed for comparing the relative hardness of cylindrical pieces. Two files, A and B, are supported upon a seating C, on a table provided with adjusting screws for levelling the surface of the lower file B before use. The lower file B is rigidly fastened to the seating C, and the upper file A is loosely hinged to the seating at one end by a knife-edge F, being provided at the other end with an extended arm carrying a weight H. The arm works in a slot in a quadrant J fastened to the seating C and provided with a divided scale indicating the inclination of the lower surface of the upper file A to the upper surface of the lower file B. The slot is formed so that the arm works quite freely therein, and the hinge connection F is also constructed so as to offer no resistance to the swinging movement of the upper file.

To use the apparatus the screws are adjusted so that the surface of the lower file B is perfectly level, and a standard cylindrical specimen piece Z of the requisite hardness and with which the other pieces are to be compared is placed upon

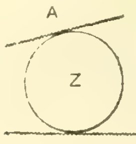


Fig. 2.

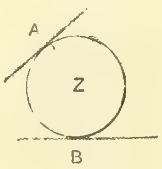


Fig. 3.

the lower file B, with the upper file A raised, and resting thereon in an inclined position as indicated in Fig. 2. The weight of the upper file resting upon the specimen piece Z will give rise to forces of which one component will be in a horizontal direction parallel to the surface of the lower file and away from the hinge and movement of the specimen piece Z in this direction will only be opposed by the resistance of the surface to the abrasion consequent upon the amount of indentation of the surface produced by the weight of the file. The harder the surface the less will be the indentation, and therefore a smaller resistance to movement relative to the abrading instrument will be offered by a hard surface than by a soft one. As the horizontal component before mentioned decreases with the angle between the files it will be clear that for conditions of equilibrium there will be a smaller angle between the files with a hard piece in position than with a softer one. The position of equilibrium for a comparatively hard steel piece Z may be as shown in Fig. 2, and the inclination of the two files may be read upon the scale attached to the quadrant J. The relative hardness of other pieces may be readily compared with that of the standard specimen piece by placing them in the apparatus and noting the position of the arm upon the scale when the upper file assumes a position of rest. This position for a comparatively soft steel piece Z is indicated at Fig. 3.

It will be understood that the abrasive action of the files will be dependent upon the relative smoothness of the surface of the pieces as well as upon their hardness, and it is therefore only possible to compare the relative hardness of pieces having surfaces possessing a somewhat similar degree of smoothness. Further, it is essential that the pieces to be compared should be applied to the apparatus in a similar manner, as the sticking friction and moving friction between surfaces differ, and if a piece has been moving horizontally in one direction prior to coming to rest, its position of rest may be different to the one it would assume if it had been moved horizontally in the other direction to a position of rest. Provided, however, that the surfaces of the pieces are similar, and that they are placed in the apparatus in a similar manner, a very accurate determination of the relative hardness of the pieces may, it is claimed, be obtained by means of the apparatus. Modified forms of the apparatus have been designed for testing spheres, internal cylindrical or concave surfaces, and horizontal surfaces.

A TORSIONMETER WITH VISIBLE SCALE.*

By Dr. K. Suyehiro, Professor of Naval Architecture at Tokio Imperial University.

Since the introduction of the method—associated with the name of Sir Archibald Denny—of finding the power of steam turbines by measuring the twist of the shaft, many instruments have been invented following the same lines. But as the measurement has to be made while the shaft is running and as the parts of a quickly rotating body are not readily visible, most torsionmeters give the twist indirectly in one way or another. The use of intermediate links, whatever be their kind—mechanical, optical, or electrical—for this purpose may become a source of error in observation.

In the torsionmeter devised by the author the number of intermediate links is reduced to a minimum. The twist is indicated directly by means of a scale and a pointer in a manner similar to that used in a statical torsional test, and the reading of the scale is taken by a simple optical device consisting of mirrors rigidly fixed to the body of the torsionmeter. The device by which the scale is made visible is as follows: In Fig. 1, let R be the cross-section of a shaft, O its axis, and S a scale fitted to the arm of the torsionmeter. It is well known that, even while the shaft is running, the scale S is visible if it is well illuminated by an intermittent light of very short duration, such as an electric spark. To emit electric sparks in proper phase with the revolution of a shaft is not a difficult matter in a physical laboratory, but is a matter of much inconvenience in the shaft tunnel of a ship; so that such a method is hopeless for practical purposes. In this torsionmeter a plane mirror M is attached to the arm just midway between O and S, with its plane perpendicular to O S. By this arrangement the virtual image of the scale S will always be formed in the axis for all angular positions of the shaft, and if the size of the mirror M is not too large the angular range through which the scale S is reflected into the eye of an observer will be small. Therefore, though S revolves with the shaft, its virtual image remains practically stationary, and as it appears successively—once in each revolution—it is as if the scale were fixed in its position.

Thus, as the scale can be made visible by such a simple device, the relative twist between two points on a shaft can be measured in a very simple manner. For instance, according to ordinary practice, let a sleeve of suitable length be clamped to the shaft at one end, its other end—carrying a pointer—being free; also, let a short sleeve mounted with a scale and a plane mirror arranged in the foregoing manner be clamped to the shaft near the free end of the long sleeve, the scale on this sleeve being so located that it comes in contact with the pointer on the long sleeve. Then the required twist may be measured while the shaft is running just as in a statical test, for the reason just described. This simple method of measuring the twist of a shaft can be applied to the line shafting of land engines, by substituting for one length a special length constructed of special steel of reduced diameter, the amount of twist being magnified accordingly. For marine use, however, where such substitution is generally inconvenient and where, in some cases, not only the maximum power, but also the power for reduced speed, has to be obtained, the measurement made in this simple manner is not sufficiently accurate; a further device is necessary for magnifying the amount of twist. In similar cases, where magnification is required, it is not uncommon to use a lever, rack and pinion, or some similar kind of mechanism. But, from the author's experience, it seems preferable to avoid such mechanism, as, even with the best workmanship and material, there can be no positive assurance of keeping free from wear during a long run. To get rid of any contact of the moving parts an optical method is again used, this time to obtain multiplication of the displacement of a pointer relatively to the scale, as described below.

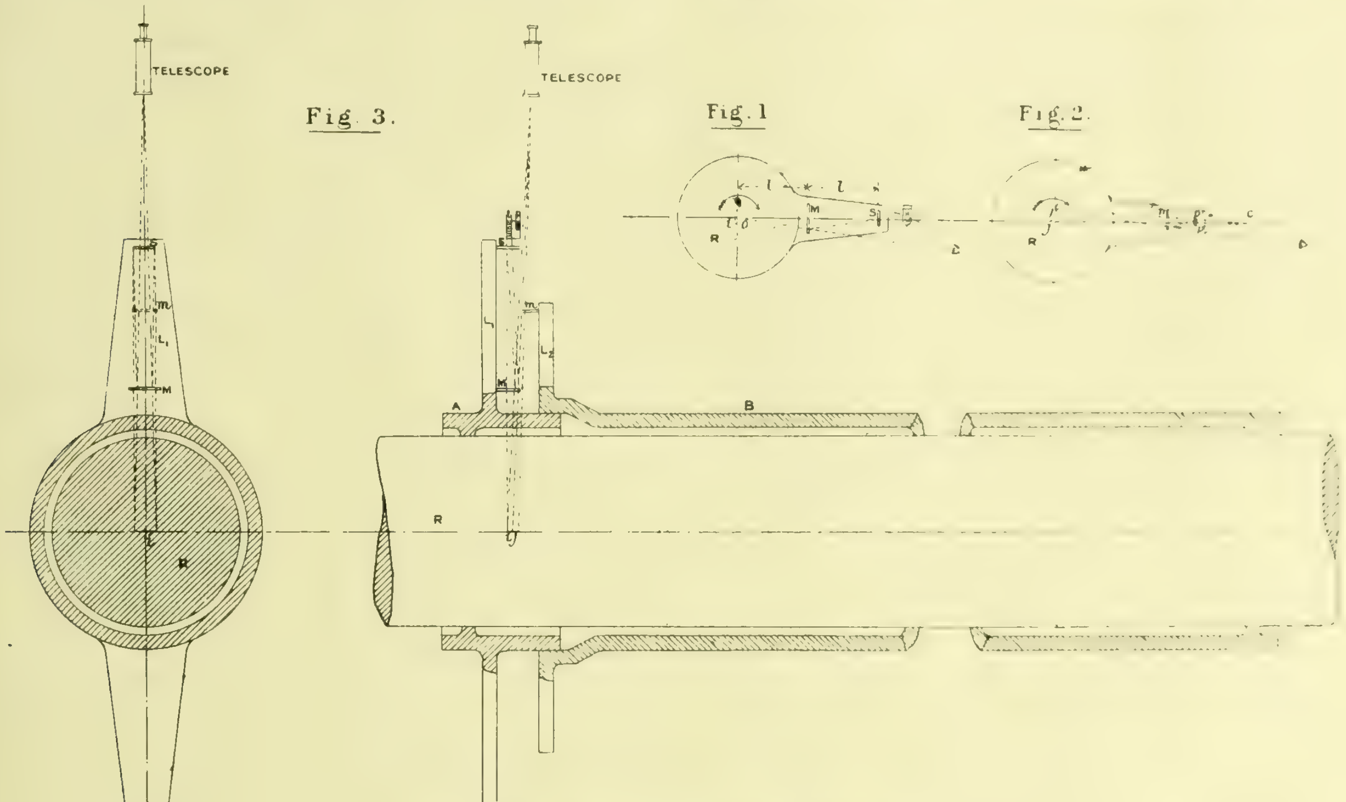
The marine torsionmeter is shown in detail in Fig. 4, and also diagrammatically in Fig. 3. As shown in the latter figure, and as described above, the torsionmeter is composed of a short and a long sleeve A and B. The short sleeve A

* Paper read at the spring meetings of the fifty-fifth session of the Institution of Naval Architects, April 2nd, 1914.

with an arm L_1 is directly fixed to the shaft, while the long sleeve B is fixed to the shaft at the far end, its near end being free and in contact with the short sleeve A. Another arm L_2 projects at the free end of the long sleeve B. On the arm L_1 a ground-glass plate S, having a scale *t* divided into $\frac{1}{5}$mm. and a "pointing edge" *p* (the transverse boundary between the white and black grounds), is fitted near the edge, and a plane mirror M is fitted in such a position that its reflecting surface is just midway between the scale plate and the axis of the shaft. The purpose of fitting the latter is to form the virtual image *i* of the scale *t* in the axis of the shaft, so as to make the scale visible, on the principle described above. On the shorter arm L_2 a concave mirror *m* is mounted in such a position that the pointing edge *p* on the scale plate is so reflected that its virtual image *j* is formed in the axis of the shaft. Thus images *i* and *j* of the scale and the pointing edge, which are cut on one and the same glass plate S, are formed separately in the axis of the shaft, the former by the plane mirror M and the latter by

curve of the "Anyo Maru," the first geared turbine steamer in Japan; two curves are shown, one giving the power as ascertained by torsionmeter, the other the power curve being deduced from model experiments previously conducted in the experimental tank belonging to the Mitsubishi Dockyard Company, the builders of the ship. Although the data supplied to me with regard to the tank experiments of the ship are rather incomplete, the long experience of the Mitsubishi firm in tank experiments may give assurance of the correctness of the curve exhibited. The close similarity of the two curves on the figure speak well for the reliability of the torsionmeter. Some of the important particulars in the case are as follows:—

Diameter of shaft .... 13½in.
Length of base .... 6ft. 6in.
Distance of scale plate from the centre of shaft .. 21in.
Magnification of twist .... 3·67 times.
One division of scale .... ¼ mm.
Maximum reading .... 37 divisions (= $\frac{37}{4}$ mm.).



Figs. 1–3. The Suyehiro Torsionmeter. Diameter 13½ ins.

the concave mirror *m*. These images are so formed that they appear side by side through a telescope placed in a proper position. Referring to Fig. 2, when the relative position *p m* of the pointing edge and the concave mirror is changed, in consequence of the twist of the shaft, to another relative position *p' m*, the virtual image of the pointing edge will be displaced from the original position *j* to the new position *j'*, the displacement being magnified according to the position and the curvature of the concave mirror. The amount of this magnified displacement *j j'* is measured by the virtual image of the scale formed by the plane mirror. A photograph of the measuring part of the torsionmeter fitted to a small electric motor, taken while the motor was running at 700 revs. per minute, and exposed during about 5 secs., shows the appearance of the images of the scale and pointing edge, and indicates that both of them seem as if they were at rest.

In measuring the power developed by a steam turbine, for which the measurement of the twist of the shaft taken at any one angular position is sufficient, one telescope placed in a proper position and a portable electric lamp illuminating the scale plate are to be used. For the purpose of measuring the shaft horse-power of a reciprocating engine, where the observation must be made at several angular positions, many telescopes should be placed in proper angular positions around the shaft, and the scale plate illuminated with an electric lamp fitted and revolving with it. Fig. 5 is the speed-power

The author's torsionmeter has so far been applied to three ships, and in each case it has worked entirely satisfactory.

SIX YEARS' EXPERIENCE WITH BONUS WAGE PAYMENTS.

BY W. L. MYLES.

The question is often asked, Does the bonus plan of work benefit the employé who performs the task? After six years of experience with this system and by close observation of its methods the writer can safely say without fear of successful contradiction that it does, and to substantiate this statement will cite some instances. Why has it become necessary to change methods of pay and work from the old day's work system of pay to bonus or any other scientific system of work which offers a reward in the form of extra compensation for greater efforts put forth? First, because competition is so keen that the manufacturer must reduce the cost of production to meet this competition successfully and keep his men engaged. Second, because labour demands its just share of the profits from that which it produces. Under the old methods of pay about 90 per cent. of the workers give their employers on an average about 60 per cent. of their capabilities, which means that 40 per cent. is wasted in some way or other. This condition is plainly noticeable to a practical eye in almost any shop where modern methods are not in force. In trying to reclaim this 40 per cent. of lost efficiency

many so-called scientific systems of wage payment have been devised; a few have met with some success, a great many have proved to be total failures due practically to "over-efficient" methods.

The system that seems to meet the demands of the employer most successfully and to benefit the working man most satisfactorily is the differential bonus piece work system of pay with a guarantee wage, because its basic principles are individual efforts with individual rewards or equal pay for equal work. Under this system the man is paid for what he accomplishes, not for the time he spends in the shop, as is the case under the day's work plan. As long as the rate paid per piece is high enough to keep him interested he will have inducements to keep at work. He will have a chance for individuality, a chance for competition, a chance for personal recognition. His liking for reasonable racing will be cultivated, also his liking for play may be cultivated. All of these incentives arise because the man feels that his sense of justice is being considered; and he realises that when the task is properly laid out and the price per piece is justly determined, he is given a square deal in being allowed to accomplish as great an amount of work as he can, with the assurance that his reward will be readily paid him. He also feels safe and willing to go ahead on the task set for him, because he has the company's guarantee that he will receive his regular day's wage in case of his failure to accomplish the task in the time allowed. It is in this particular instance where straight piece work falls down in that it provides no compensations for the man's efforts in case of failure to come up to the time allowed.

One of the great advantages that this system of pay has over straight piece work is that there are no cuts in the time or rate allowed per piece; a time once determined becomes standard. Because of this the man's attention is always concentrated on his work and not distracted, as it surely must be in the straight piece work system where continual cutting of the time and rate is practised so freely. It also benefits the working man because of the chance afforded of individuality; he does not have to divide the spoils with some fellow-worker who may not have put forth the same amount of energy in the accomplishment of the task, but received the full reward nevertheless. It benefits the working man by reducing to a large degree the physical effort formerly put forth in his work, for under this system the mechanic is instructed as to the best methods of performing his work; and by following the instructions given him, he soon realises that by the co-operation of his brain and hands less physical effort is required. In a shop where this system is in force the men are doing 40 per cent. more work, with about 25 per cent. less physical effort. This is possible because this system automatically forces the brains of the management to co-operate with the efforts of the men in the shop, the employé receiving his share of the benefits through this co-operation.

Some of the benefits derived by the men under this system can readily be seen from a report taken from one of the leading manufacturing concerns of New Jersey where both skilled and unskilled labour have shared in its benefits. The report shows that for a period of 12 months the average net increase for mechanics per hour was 6.1 cents, or 26 per cent.

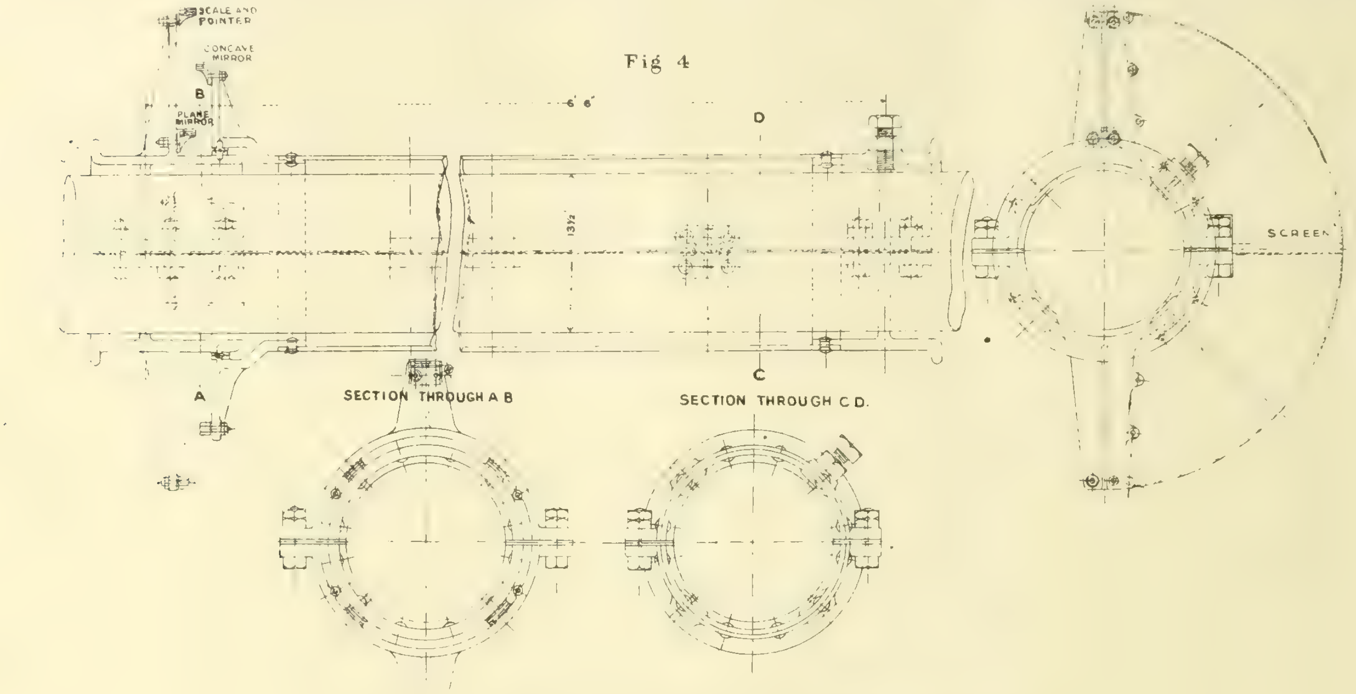


FIG. 4.—THE SUYEHIRO TORSIONMETER, DIAMETER 13½ INS. (See page 372.)

Comparison Table of Results Obtained under the Old and New Systems of Pay.

Operation.	Day Work Plan.		Bonus Plan.		Advantage of Bonus Plan.			
	Time taken per Piece, Hour.	Mechanic's Hourly Rate, Cents.	Time taken per Piece, Hour.	Mechanic's Hourly Rate, Cents.	Increase in Rate per Hour, Cents.	Percentage of Increase in Wage.	Percentage of Decrease in Cost.	Increase in Efficiency, per Cent
Radial drill job	⅔	23	¼	30	7	30	47	62
Milling machine job	45	35	16	43	8	25	56	64½
Drill press job No. 1	20	23	14	28	5	22	15	30
Drill press job No. 2	3½	25	1½	32	7	28	45	57
Drill press job No. 3	15	28	8	37	9	32	30	47
Boring mill job	30	32	16	42	10	31	30	47
Lathe job No. 1	3	34	1	44	10	30	57	66⅔
Lathe job No. 2	2	34	1	45	11	32	34	50
Planer job	23	33	13	42	9	27	28	43½
Large mill job	11	35	5	45	10	29	40	55
Forging job	2	40	⅝	52	12	30	46	58
Vice and floor job	16	34	7	46	12	32	35	44

higher wage. The average increase for unskilled labour was somewhat higher, due to the fact that they were put on jobs that were rated at a higher rate of pay than they were receiving for the day's work, for under this system it is equal pay for equal work. that is, if a 20-cent-per-hour man can do the same work satisfactorily and in the time allowed as a 35-cent-per-hour man can he is justly entitled to equal pay on that job. The benefits derived from the educational value of this system are in no way small. By following the instructions and methods of this system, the men learn to rely upon themselves and acquire a self-sustaining power. There is no need of the foremen speeding the men up to a point where, as soon as he leaves, the worker naturally slows down. The reward offered induces enough incentive to the man to speed himself up without the supervision of a gang boss.

The accompanying table is a good illustration of some of the direct benefits obtained from the differential bonus plan of wage payment to men on various operations, compared with former rates. In one manufacturing establishment where the bonus got to be such a big proposition that it became necessary to have two pay days (one for the bonuses or rewards that were earned by the men, which they received

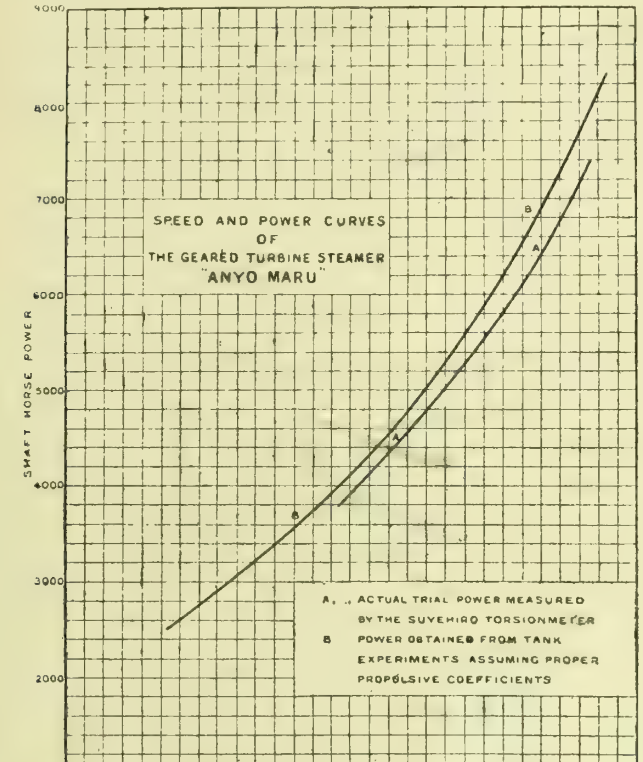


FIG. 5. (See page 373.)

each Wednesday, the other the regular pay day on Saturday), a blue envelope was provided for the bonus mid-week pay day and all bonuses earned up to Tuesday night were paid the men Wednesday noon. This scheme was readily appreciated by the men, as they receive direct benefit of their efforts as soon as their task is accomplished. This also helps to tide over those who develop financial weakness about the middle of the week and "borrowing on account" has been greatly reduced. But the greatest benefit obtained by the bonus envelope is the feeling that it represents a personal reward for extra efforts and is in addition to the sum which, received at week-ends, may be regarded as covering the regular living and home expenses.

But you may ask, "How about the poor fellow who does not earn a bonus? What effect does it have on him?" It arouses and cultivates that zest for reasonable racing, with the possible chance of beating his fellow-workman, and before long he becomes so efficient in his work that he too receives his blue bonus envelope on Wednesdays. Without a doubt, the adoption of this plan of wage payment of equal pay for equal work is the most satisfactory to both employer and employé in that it supplies the needed incentives, forces co-operation of both party's interest in the work, obtains and maintains an efficient force of men, and is a long stride toward social justice.—"The Iron Age."

INDUSTRIAL AND TRADE NOTES.

Messrs. Sir W. H. Bailey & Co., Ltd., Albion Works, Salford, Manchester, have just received an order through their agents, Messrs. R. H. Longbotham & Co., Ltd., Wakefield, for one of their "Köster's" patent electrically-driven air compressors to deal with 1,600 cub. ft. of free air per minute, for the Consett Iron Company, Ltd., Consett, Co. Durham.

Mine-experiment Station at Pittsburg. It is proposed to erect at a cost of £100,000 a mine-experiment station at Pittsburg, Penn U.S.A. A series of mine shafts will be provided. One will be used as an elevator, another for tests of mining appliances, *e.g.*, hoisting ropes, while a third will give entrance to tunnels extending under the buildings, in which mining experiments will be conducted.

International Congress of Chambers of Commerce. The 6th International Congress of Chambers of Commerce will be held in Paris from the 8th to 10th June next. Amongst other matters the Congress will discuss the utility of international action against unfair competition, the unification of the laws relating to arbitration proceedings between inhabitants of different countries, and the question of unification of the laws relating to credit on goods.

Electricity in Fiery Mines.—At the South Wales Miners' Federation annual conference, at Cardiff, on the 7th inst., there was a long discussion on a resolution, which was eventually carried, to seek prohibition of the use of electricity for motive power in fiery mines. The matter arose out of statements at the Senghenydd explosion enquiry, and the danger of the emission of sparks from cables was emphasized by Mr. T. Richards, M.P. (general secretary of the Federation). It was pointed out that many newly-equipped collieries had installed electrical plant.

New Joint Railway.—The new railway which is to be owned jointly by the Great Central and Hull and Barnsley Companies will extend from Gowdall, on the Hull and Barnsley main line, to Braithwell, where it will connect with the Great Central, the Hull and Barnsley, and the Midland Joint line. It will provide direct communication with the new collieries at Bullcroft, Bentley, and Edlington, and form a junction with the Great Central Railway Company's new Doncaster line at Hexthorpe. The line, which has a length of 22 miles, will probably be completed by the end of the current year.

Reduction of Customs Duty on Pig Iron Imported into Russia.—It was decided, at a meeting of the Council of Russian Ministers, held last month, to permit the importation into Russia from abroad of foreign pig iron, at reduced rates of Customs duty, to the end of December, 1915. The total amount, the importation of which is to be allowed during this period at the reduced rates of duty, will not exceed 323,000 tons. Special application will have to be made in respect of every consignment which it is proposed to import, and the actual reduction of Customs duty to be granted will be determined separately in the case of each consignment. A Bill embodying these provisions will be laid before the Imperial Duma by the Ministry for Commerce and Industry at once.

International Trade Convention.—As a result of the conference held in November, 1913, at Brussels, for the purpose of considering the possibility of drawing up a scheme for the publication of international trade statistics, a convention has been signed by the 29 countries represented creating at Brussels an International Board of Commercial Statistics. This convention, according to "The Times," will come into force on July 1st next, and preparations are being made to give effect to it. Apart from the ordinary trade returns issued by each country, the convention provides for the preparation of special statistics, drawn up on a uniform basis, showing the exports and imports of certain classes of goods. The weight of the goods will be indicated wherever possible, as well as the value. The publication of these returns will be made in the form of a bulletin printed in the French language

Board of Trade Commercial Intelligence Committee.—A meeting of the Advisory Committee to the Board of Trade on Commercial Intelligence was held in London, on the 7th inst. Amongst the matters considered by the committee were the arrangements in connection with the special Commercial Mission to Siberia, to be undertaken forthwith by Mr. H. Cooke, H.M. Commercial Attaché for Russia; a special Commercial Mission to China; proposals for the re-classification of goods for the purposes of the Trade Marks Act; and possible action for the removal of difficulties caused to traders by differences in the legal procedure of the United Kingdom and certain other European countries. It was reported that the number of enquiries received at the Commercial Intelligence Branch during 1913 was 16,668, and that the number of reports (other than annual reports) received from H.M. Legations and Consulates, and from H.M. Trade Commissioners and the Trade Correspondents, and utilised by the branch, was 4,082, as compared with 3,754 in 1912.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1913.

Valve mechanism for internal combustion engines. Dawapurarathna. 6883.
Stop valves. Williams & Wrightson. 6973.
Apparatus for automatically preventing overwinding of colliery cages. Bayley & Froggatt. 6990.
Water cooling apparatus. Powel & Berry. 7057.
Engine-starting devices. Prescott. 7282.
Carburetters for internal combustion engines. Skelton. 7370.
Internal-combustion engines. Cox. 7475.
Means for indicating variations of temperature of the cylinders of internal combustion engines. Boyce. 7679.
Means for circulating the cooling water of explosion engines. Blackstone, Carter, & Carter. 7743.
Acetylene gas generators. Davis. 8258.
Centrifugal pumps. Gerdau. 8678.
Blades for steam turbines. Dianovszky & Schlegel. 8793.
Apparatus for automatically controlling temperature. Wilkinson. 9011.
Processes of treating metals. British Thomson-Houston Company. 9097.
Silencer for internal combustion engines. Bottomley. 9111.
Apparatus for the direct conversion of heat into electricity. Gyuris, and Alois Schlesinger. 10036.
Carburetters of internal combustion engines. Leeke & Wilesmith. 10117.
Drilling and boring apparatus. Bambridge. 10139.
Screw or worm conveyers. Bourcoud. 10207.
Oil blast burners. Fletcher, Russell, & Co., and Fletcher. 10316.
Water-tube boilers. Mellersh-Jackson. 11458.
Rotary internal combustion engines. Nield. 11522.
Means for preventing the leakage of oil from bearings. Stead and National Gas Engine Company. 12039.
Automatic timing apparatus particularly applicable to the regulation of the stoking of boiler furnaces. Evershed and Vignoles, Ltd., Kilroy, & Needham. 13228.
Rotary cylinder engines. Soc. Clerget et Cie. 13333.
Drilling machines. Asquith, and William Asquith, Ltd. 14154.
Horizontal face-plates for lathes. Compagnie des Forges et Aciéries de la Marine et d'Homecourt. 14691.
Cutter-holders used in cutting gear teeth. Sykes. 15862.
Alloy. Westley. 15982.
Means for securing boiler tubes. Downer. 15998.
Exhaust silencer for internal combustion engines. McPherson. 16336.
Speed indicators. Ufert. 17933.
Carburetters for internal-combustion engines. Soc. J. Grouvelle, H. Arquembourg, et Cie. 18081.
Balanced double-beat steam regulating valve for locomotives. Lockyer. 18209.
Double helical gearing. Thorne. 18370.
Process of heating and moulding metals. De Lostalot. 18510.
Cupolas. Tropenas & Tournier. 20921.
Silencers for internal combustion engines. Lelarge. 21228.
Steam dryers and oil separators. Ogden. 21731.
Supply of air to boiler and other furnaces. Davison. 21788.
Carburetters for internal combustion engines. Soc. M. Goudard et Mennesson. 21952.
Smoke consuming fire bridges with regulatable air supply. Brill. 22109.
Apparatus for charging blast furnaces with incandescent coke. Semmler. 22873.
Utilisation of waste heat of iron works. Semmler. 22875.
Casting compound steel ingots. Fuery. 23622.
Slides of shaping machines. General Composing Company. 24165.
Change speed gear. Magnat & Moser. 26722.
Lubricating apparatus for internal combustion engines. Daimler Motoren Ges. 27545.

1914.

Steam generators. Robinson. 338.
Steam heated radiators. Schroder. 1361.
Elastic fluid motors. Daniel. 1104.
Fluid control valves. Sperryn & Co., and Jones. 1831.

ELECTRICAL, 1913.

Receiving apparatus for wireless telegraphy. Chambers. 4779.
Electrical switches. British L.M. Ericsson Manufacturing Company and Rogers. 6873.
Protecting electrical instruments from being operated by extraneous currents. Dormer. 6900.
Overhead conductors for electric traction systems. Bowen and Cedes Electric Traction, Ltd. 7305.
Dynamos. British Thomson Houston Company, Clough, and Dunker. 7600.
Transmitting apparatus for wireless telegraphy and telephony. Marconi & Franklin. 7610.
Detectors for use in wireless telegraphy. Graham & Latham, Ltd., Graham, & Sobotka. 7977.
Electric incandescent lamp holders. Wilkinson. 10004.
Substitution resistances for electric lamps. Heins. 10252.
Electric arc lamps. British Thomson Houston Company. 10301.
Electric time switches. Thompson & Bowden. 11057.
Indicating appliances for electric measuring instruments. British Thomson Houston Company, and Holden. 12839.
Electric dimming switch. Hulbert. 13023.
Electric arc lamps. Railing & Angold. 14071.
Securing of windings in dynamos. Siemens Bros. Dynamo Works, Ltd., Koettgen, & Kieffer. 15148.
Electric water gauges. Rajczy. 16691.
High speed rotors for high-frequency multipolar electrical machinery. Goldschmidt. 17268.
Electricity meters. Korting & Mathieson Akt. Ges. 27875.

1914.

Electric time switches. Bérand. 915.

METAL QUOTATIONS.

TUESDAY, APRIL 14TH.

Aluminium ingot	85/- per cwt.
,, wire, according to sizes, &c. ......from	112/- ,,
,, sheets ,, ,, ... ,,	112/- ,,
Antimony	£27/10/- to £29/10/- per ton.
Brass, rolled	7¼d. per lb.
,, tubes (brazed)	9⅝d. ,,
,, ,, (solid drawn)	7⅞d. ,,
,, ,, wire	7⅜d. ,,
Copper, Standard	£64/17/6 per ton.
Iron, Cleveland	51/3 ,,
,, Scotch	57/3 ,,
Lead, English	£18/15/- ,,
,, Foreign (soft)	£18/2/6 ,,
Mica (in original cases), small	6d. to 3/- per lb.
,, ,, ,, medium	3/6 to 6/- ,,
,, ,, ,, large	7/6 to 11/- ,,
Quicksilver	£7/-/- per bottle.
Silver	26 13/16d. per oz.
Spelter	£21/10/- per ton.
Tin, block	£167/7/6 ,,
Tin plates, I.C.	12/10½ per box.
Zinc sheets (Silesian)	£24/15/- per ton.
,, (Stettin; Vieille Montagne)	£25/2/6 ,,

The Cunard Fleet.—The fleet of the Cunard Steamship Company, Ltd., comprises 27 steamers and tenders, having an aggregate displacement of 284,097 tons, and propelled by engines working up to 309,800 h.p. The following three steamers are now building, and will shortly be added to the fleet: "Aquitania," for the Liverpool and New York mail service; "Transylvania," for the New York and Mediterranean service; and "Aurania," for Canadian service.

Accident to a Scotch Express.—A collision, involving the loss of two lives and injuries to 12 passengers, occurred early on Tuesday morning on the North British Railway at Burntisland, Fifeshire. The 3-55 express from Edinburgh for Aberdeen reached Burntisland about 4-50, and just outside the station ran into the front portion of a goods train which was being shunted into a siding. Travelling at the rate of about 40 miles an hour at the time, the impact was so great that the express engine left the rails, together with the front coach and three luggage vans, broke through a low wall, and toppled over into a public park. Unfortunately, the driver and fireman of the express had no chance of escape, both being buried under their engine and killed outright. Twelve passengers in the front carriage were injured more or less seriously. The wreckage of the leading coach caught fire following an explosion, but, profiting by the lesson of the Aisgill disaster, there were patent fire-extinguishers on the train, and the guard speedily extinguished the flames.

The Mechanical Engineer.
AN ILLUSTRATED WEEKLY JOURNAL Vol. 33, No. 848

Edited by
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Telegrams: "Scientific," Manchester.
Telephone No. 6055 City.

SUBSCRIPTION RATES.

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Advertisements, displayed, for insertion in current issue should reach our Manchester office not later than first post Tuesday morning, and small prepaid advertisements not later than first post Wednesday morning.

Board of Trade Enquiries into Boiler Explosions.

WE have more than once referred to the whimsical manner in which the Board of Trade appears to exercise the power it possesses under the Boiler Explosions Acts in ordering a formal enquiry to follow the preliminary enquiry which is always held. We touched on the matter so recently as February last (*see* p. 114 ante), and since then a report, No. 2281, has been issued respecting an explosion which occurred at a colliery at Dalry, in Scotland, which adds point to our remarks. The boiler was of the Lancashire type, measuring 30ft. in length by 7ft. 6in. diam., and there was no doubt as to the cause of failure. It was due simply to corrosion at the bottom of the shell arising from neglect, with the result that the plates eventually became too weak to withstand the ordinary working pressure, and were ripped open. The boiler was hurled from its seat and landed on to a railway truck in a siding 30ft. away, while an adjoining boiler was dislodged, the steam pipes and connections wrecked, and the engine-man badly injured. From the report of the preliminary enquiry, which was the only investigation that was held, it appears that the boiler was not enrolled with any inspection or insurance company, and that the only examination it received was at the hands of a boiler smith in the employ of the company, whose qualifications for the duties of a boiler inspector were very imperfect. That his inspection was inadequate is evident from the fact that the boiler, where it gave way, was wasted by external corrosion until the plates, originally $\frac{7}{16}$in. thick, were as thin as a sixpence, and this corrosion must obviously have been in existence for a long time. The case was precisely one in which it appears to us that the powers designed for the Board of Trade to expose incompetent inspection and neglect by ordering a "formal" investigation, and if need be, inflicting costs, might very well have been exercised. Such punishment. It

may be here remarked to those who are not familiar with the clauses of the Boiler Explosions Acts, is not possible with a "preliminary" enquiry, as, although a report is published, the enquiry is in the nature of a private investigation by a Board of Trade engineer. Now, the explosion, without doubt, was a serious one, and the report states that "in view of the extreme thinness of the plate it can only be inferred that the examination of the boiler (made six months before the explosion) was inadequate." Further, alluding to the boiler smith who made the inspection, it adds, "it is very doubtful whether he could be considered a 'competent person' to examine and assign the working pressure of a steam boiler." No reflections are cast by the report upon the conscientious manner in which the boiler smith endeavoured to discharge his duties, but this in no way detracts from the fact that he was incompetent, and that as a result of this a disastrous explosion ensued. The man may not have been to blame for his imperfections, but the owners were certainly responsible for employing him to discharge the duties of a boiler inspector, and the Board of Trade Commissioners have again and again stated that ignorance cannot be pleaded as justification in such circumstances. It is interesting to contrast this case with another (*see* report No. 1684), relating to the "explosion" of a water tube boiler at Leamington. In this case the so-called explosion, with respect to which a formal enquiry was ordered and gravely enquired into by two Board of Trade Commissioners for two days, consisted of a crack ⅝in. long in a 4in. water tube of a Babcock & Wilcox boiler. Whilst we agree with the Commissioners, who stated in this latter case "that the extent of an explosion is no test as to the desirability or otherwise of holding a formal investigation," it is impossible to avoid feeling that if a formal enquiry was called for in the Leamington case it was infinitely more urgent in connection with the explosion at Dalry. It is, of course, easy to criticise the working of any public department, but our remarks are not directed by a captious spirit. We are fully conscious of the good work that has been done by the Board of Trade in the administration of the Boiler Explosions Acts, and if the examples we have given were solitary ones they might be allowed to pass, but they are not, and it does seem as if the discretionary powers which the Board exercises in respect to the appointment of "formal" enquiries might be used with greater consistency.

Condenser Tubes.

A CONDENSER tube appears an insignificant detail, but probably no part of a ship's equipment has caused at one time or another greater trouble and anxiety, or had more care and thought spent on its composition. The peculiarities of the corrosion and splitting to which it is liable, and which are the chief source of the difficulties associated with it, have formed the subject of numerous researches which have been described before engineering societies from time to time, and Sir Henry J. Oram, Engineer-in-Chief of the Fleet, in his presidential address before the Institute of Metals recounted the experience of the Admiralty, which is interesting not only as showing how engineering worries may arise from a trifling detail, but how they may be finally conquered by patient investigation and research. To this end, the special committee appointed by the Institute of Metals to enquire into the matter has contributed very materially, and due credit was paid by Sir Henry, on behalf of the Admiralty, to the value of the second report read at the Ghent meeting last year. That report largely confirmed Admiralty experience during the last 20 or 30 years, but this is seldom published, and for this reason the detailed record of it set forth by him and which we reproduced in our issue of March 27th (see page 294 ante), deserves the careful attention of all who are interested in the question. How largely the troubles have been removed by selection of suitable alloys and care in testing is shown by some figures quoted in the address. It is impossible to give the number of failures that occurred in the early years, as no records were kept, but Sir Henry states they were very numerous, while his figures show they are now practically eliminated. In 1908 the approximate number of condenser tubes at work in the British Fleet was 2½ millions, and the number of failures occurring on service only totalled 90, or at the rate of 1 in 28,000 per annum, and even this slight percentage has been considerably reduced, for in 1913 the total number of tubes in service was approximately 3,800,000, and the total failures only 131, *i.e.*, 1 in 60,000 per annum. This excellent result has been mainly attained by a happy combination of the experience of the user with the experimental work of the laboratory and the commercial possibilities of the manufacturer, a combination powerful to solve difficulties, but unfortunately, owing to trade jealousies, not always possible to bring about.

WASTE HEAT BOILERS AT OPEN-HEARTH FURNACES.

AN American contemporary gives some interesting data relative to economies developed by the installation of waste heat boilers in connection with the open-hearth furnaces at the South works of the Illinois Steel Company. Previous to putting in the boilers all the steam used by the gas producers was obtained from the blooming mill boiler house through a long steam main. This resulted in very low steam, both as to pressure and quality, at the south end furnaces. The first boiler to be put in was a small Heine of 1,900 sq. ft. of water-heating surface. A fan driven by a vertical high-speed engine draws the stack gases from the furnace through the boiler and discharges back into the furnace stack. The improvement in steam conditions was very marked, the pressure then being raised from 50lbs. to about 100lbs. However, the results often showed that the boiler and fan were much too small, as only a small part of the available heat was abstracted from the waste gases, so another installation was made of two Stirling boilers of 4,000 sq. ft. of heating surface and much larger motor-driven fans. As originally installed, these boilers had heaters in the breeching to heat the feed water, but the flue dirt in the gases caused so much trouble by clogging up the spaces in the heaters that they were taken out. The present feed-water system carries out the idea of waste heat utilisation to the utmost extent and is as follows: The warm waste cooling water from the bulkhead and port pipes of the furnaces is supplied to the Dyblie gas valve hood instead of cold water. After being heated still further by the gas valve, it flows from a semi-circular trough to a small tank, the water level of which regulates the amount supplied to the Dyblie valve hood by a float valve according to the requirements of the boilers. From the small tanks the water flows through a pipe under the floor to the feed pump, but, before entering, the exhaust steam from the feed pump is discharged into the water. These three additions of heat are sufficient to raise the feed water from 35° to 200°, equivalent to 90 boiler horse-power. The boilers are now making about 825 boiler horse-power, which is equal to 1,900 tons of coal a month obtained from waste heat.

A CURIOUS BREAKDOWN OF AN OIL ENGINE.

THE April issue of "Vulcan" gives particulars of a rather curious breakdown of an oil engine arising from the presence of water in the cylinder which is worth noting by users of this type of prime mover which work in dusty atmospheres and where water filtering arrangements are used to eliminate dust from air drawn through the air inlet for the compression charge. The breakdown of steam engines by a sudden rush of water into the cylinder is, our contemporary observes, not uncommon, as steam is so easily converted to water by lowering of temperature. Condensation in steam pipes is responsible for a large number of such breakdowns, as well as the sucking up of water into the cylinder of a condensing engine from the

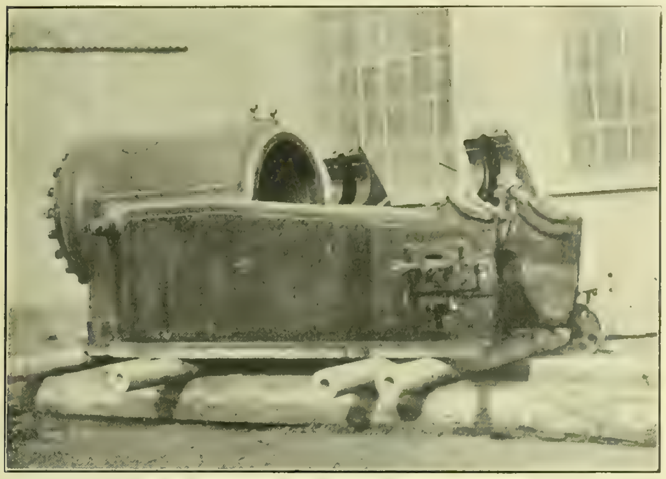


FIG. 1.—BREAKDOWN OF AN OIL ENGINE.

condenser and air pump. In the case of gas engines, breakdowns are also caused occasionally by water in the cylinder, though they are rarer than similar breakdowns of steam engines, as a leaky liner joint or a fractured breach end seldom allows a sudden rush of water from the jacket sufficient in quantity to fill the clearance space of the combustion chamber, and bring the piston to a dead stop whilst working. We have on the present occasion a still rarer experience to record, namely, the disastrous breakdown of an oil engine at a cement works, caused by water in the cylinder, and on this page we publish two photographs of the broken bedplate and frame of this engine, which had a cylinder 12in. diam. by 1ft. 6in. stroke, and ran at 230 revs. per minute. One afternoon when starting the engine it was noticed that water began to squirt out of the cylinder, accompanied by a heavy knock, and before the engine could be stopped by shutting off the oil supply the smash occurred. The front part of the bedplate was completely carried away, the crank shaft bent, and considerable other minor damage done. On investigation it was found that the air filter on the air inlet was responsible for the trouble. This filter was of special design, owing to the extremely dusty character of the atmosphere, and the filtering medium was water, but owing to a defect in the arrangement water had accumulated in the horizontal portion of the air pipe to the engine to such an extent that it was drawn into the cylinder when the engine got under speed, with the results described.

QUALITY OF LUBRICATING OIL AFTER LONG USE.

THE results of a series of tests of lubricating oil to determine whether it "wears out" or not in long-continued service appeared in a recent issue of "Engineering News." The tests were made by Prof. R. C. Carpenter and Prof. W. M. Sawdon, at Cornell University, for the Richardson-Phenix Company. Samples were secured of filtered oil from a power plant in New York City, where an installation of this company's central oiling and filtering system has been in service one and a half years.* For comparison samples of fresh oil of the same quality and brand were secured. A few of the comparative results of the study of physical properties are given below:—

Colour.	New oil Medium red; translucent.	Old oil Dark red; opaque.
Flash point open cup	410° F.	410° F.
Burning point open cup	460° F.	440° F.
Specific gravity[1]	0·895	0·903
Relative viscosity[2]	70° F. 3·48	70° F. 4·66
	97° F. 2·14	103° F. 2·16
	130° F. 1·63	130° F. 1·62
	215° F. 1·22	218° F. 1·19

[1]Water = 1 at 60° F. [2]Water = 1 at 60° F., 27·9 sec. 100 cm., Olsen viscosimeter.

A series of tests were also made on a Thurston railroad-lubricant tester (hardened steel journal and bronze bearings of 20 sq. in.). The machine was run at constant speed of about 360 revs. per minute and bearing load applied in increments up to 75lbs. per square inch. Oil was fed as nearly constantly as possible. Test at each load was continued until friction and temperature had become constant. The following figures have been taken from the data of these runs:—

	Bearing pressure; lbs. sq. in.	Duration test; minutes.	Temp. diff.: bearing and room.	Minimum coefficient friction.
New	75	120	46·3	0·01166
Old	75	150	46·0	0·01265
New	150	50	49·3	0·00666
Old	150	60	50·7	0·00717
New	225	60	58·0	0·00533
Old	225	60	57·2	0·00522
New	300	60	66·5	0·00458
Old	300	80	67·5	0·00458
New	375	50	70·5	0·00373
Old	375	50	59·7	0·00367

From the first table it is seen that the old oil had gained in specific gravity—as would be expected through loss of volatile constituents and the addition of small quantities of

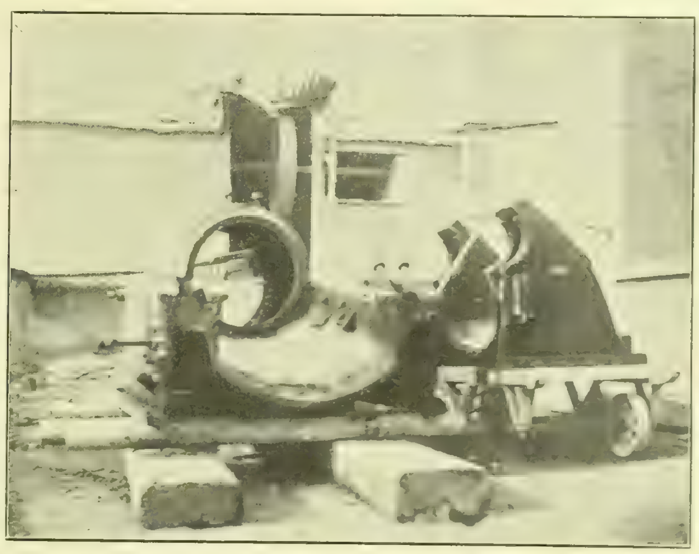


FIG. 2.—BREAKDOWN OF AN OIL ENGINE.

cylinder oil from piston rods and stuffing-boxes. The used oil showed a higher viscosity than the new, indicating that it gained in "body" with use. The friction tests showed consistent results; the new oil had a slightly lower coefficient of friction on low-bearing pressures, while the reverse is true for the higher pressures. The changes are so small, however, that the values are alike for all practical purposes.

* Tests at the plant showed a circulation of 3,600 gallons of oil per day, or about 1,800 bbl. per month. About 3 bbl. of fresh oil are added each month to make up for losses and withdrawals. Some four gallons of water per day are separated from the oil.

Tramway Goods Service.—The Liverpool Tramways Committee are entering into negotiations with the South-west Lancashire tramway companies with regard to the inauguration of a tramway goods service between the Liverpool docks and Bolton, Bury, Rochdale, and other Lancashire towns.

HIGH-SPEED BEARINGS.*

BY GERALD STONEY, F.R.S.

There are three principal types of friction in all bearings. (1) Contact friction, where both surfaces are dry, and this type was investigated as early as 1781 by Coulomb, who found for pressures from ¾lb. to 100lbs. per square inch and speeds up to 10ft. per second that the friction was independent of the pressure per square inch and the velocity; but was proportional to the total force pressing the surfaces together, and was dependent also on the nature and material of the surfaces.

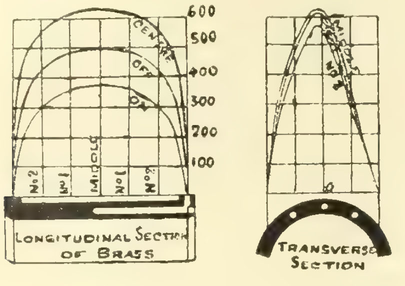


Fig. 1.

(2) Greasy friction, where there is more or less complete lubrication and a more or less complete film of oil between the surfaces. This has been investigated by many experimenters, but concordant results have not been obtained as so much depends on the degree of lubrication. Generally speaking, however, friction of this kind is proportional to the load and is independent of the speed, *i.e.*, the coefficient of friction is constant. (3) Complete lubrication, where there is a complete oil film between the surfaces and there is no metallic contact. This usually occurs in high-speed journal bearings where bath or forced lubrication in some form is provided.

The theory of complete lubrication may be said to have originated in 1884 at the British Association meeting at Montreal. In Lord Raleigh's address (page 13 of B.A. Report, 1884), he mentions Towers' experiments and shows that the incoming layer of oil is thicker than the outgoing. He mentions, moreover, that some additional elucidation of the phenomena might be expected from Prof. Stokes, afterwards Sir George Stokes, but there is no further record of this in the B.A. Report. There was also a paper read by Prof. Osborne Reynolds before Section A on "The Action of Lubricants," but no more than the title of this is given. Lord Raleigh pointed out the value of Towers' experiments with complete lubrication, and how they upset ideas previously widely admitted, and that the results showed the friction to be nearly independent of the load and much smaller than generally supposed, giving a value of μ as low as $\frac{1}{1000}$. He also directed attention to the fact that the weight on the bearing was really borne by the oil film which was thicker at the ingoing than at the outgoing edge, and that the oil must have a certain viscosity proportional to the pressure.

It is evident that both Lord Raleigh and Prof. Stokes saw that the problem could be attacked mathematically, but until Prof. Reynolds in 1886 ("Phil. Trans.," 1886) effected the integrations in certain cases nothing further was done. Even the integrations then effected are in most cases approximate only. Prof. Reynolds, in fact, worked out two cases, first that of a flat surface (of finite length in the direction of motion, but of infinite length at right angles to it), moving over another flat surface, and secondly, the case of a shaft running in a bearing of infinite length. The bearing assumed in his calculations was semi-circular and of slightly larger radius than the shaft. He showed that the theory thus established gave results in very close agreement with Towers' experiments. A further extension was made by Sommerfield ("Zeitschrift fur Mathematisch und Physic" Band 50) and Michell (*Ibid.*, Band 52). The latter worked out the distribution of pressure, the coefficient of friction and the angle of the surfaces for the cases of a square plane, a plane with the length three times the width, a plane of infinite length, and a plane of infinite width, and it was on this investigation that he based his well-known pivoted thrust bearing.

* Abstract of paper read before the North-east Coast Institution of Engineers and Shipbuilders.

The case usually occurring in practice of a journal of finite length bearing on only, say, one-third of the complete circumference has not, so far as can be traced, had the necessary integrations made, and so we have to fall back on experimental results. Towers experimented with a bearing 4in. diam. and 6in. long, the brass embracing the full half circle and being accurately scraped to an easy fit to the shaft. The brass was on top and the shaft dipped into an oil bath so as to ensure complete lubrication. He found that the oil film was under very considerable pressure and that the distribution of pressure was as shown in Figs. 1 and 2, with a nominal load of 333lbs. per square inch. The general result was that with olive oil at 90° Fah. the friction was nearly independent of the pressure, and increased approximately as the velocity $V^{0.6}$.

Fig. 3 shows the average of his results, V being in feet per second, ρ being the shear resistance per square inch taken on the projected area of 24 square inches.

In the range of his experiments with pressures from 100lbs. to 500lbs. per square inch of projected area there was little change in the value of ρ

Fig. 4 shows the relative viscosity of the oil at various temperatures, from Osborne Reynolds' experiments. The dotted part is extrapolated by his formula.

Goodman (Manchester Association of Engineers, 1890) experimented with a bearing 2in. diam. and 4in. long running at 233 revs. per minute, equivalent to a surface speed of 2·04ft. per second, with an oil bath maintained at a temperature of 40° C., and found little difference with loads varying from 50lbs. to 550lbs. He also found that the total friction was inversely proportional to the arc of content, which he varied from the full width of 2in. down to ½in., the shear resistance being constant at 0·36lb. per square inch taken on the chord of the arc of contact. This reduction of the arc of contact has been used in railway journals to reduce the friction.

The chief published experiments on high-speed bearings are those of O. Lasche ("Traction and Transmission," Vol. 6, No. 22, 1903). These tests show that so far as friction is concerned it is not well to use a large shaft and a long bearing, but experience shows that for high speeds and heavy loads long bearings are necessary, and they have also to be large to avoid vibration and critical speeds, and also the risk of fracture due to vibration. To avoid this latter danger the bending stresses have to be kept to a figure which would be considered very low in ordinary practice, as there have been several cases of fracture of shaft ends. If the pressure is too high or the oil is too thin a bearing may run all right so long as there is no vibration, but if vibration occurs the oil film

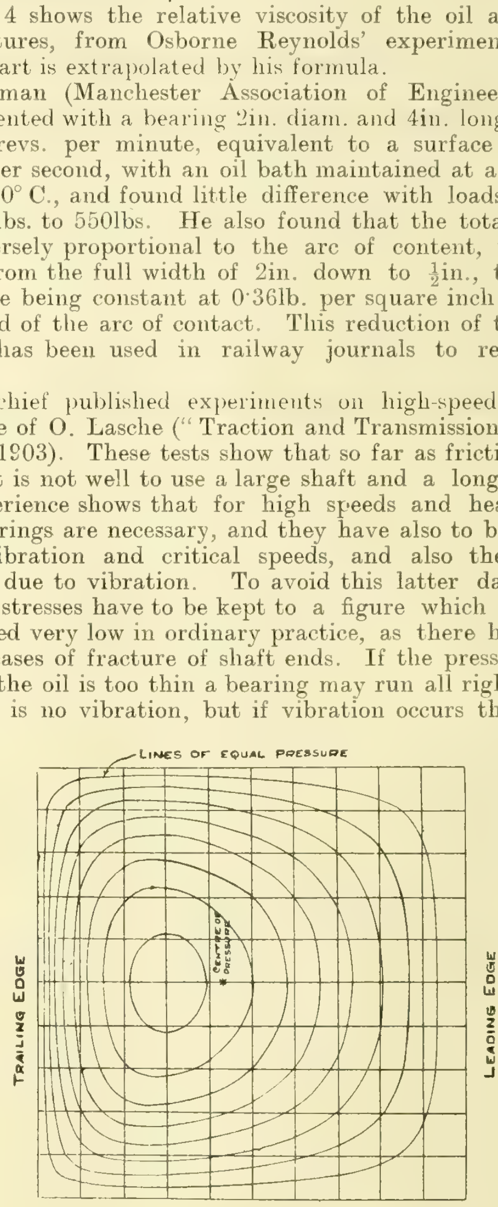


Fig. 2.

may be driven out and seizing take place. This is especially liable to happen with the shafts of electrical machinery, such as the armatures of dynamos and rotors of alternators, where there is always a liability to vibration due to their going out of balance, and it is probable that much lower pressures are advisable in such cases than in those of turbine rotors, which from their construction are not, as a rule, so liable to go out of balance.

This effect is reduced in very high-speed shafts, above, say, 2,000 revs. per minute, by the use of the well-known Parsons' flexible bearing, where there are two or more tubes outside the bearing bush with a small clearance between them in

which the viscosity of the oil tends to damp out vibrations. In turbine work, a rule much used for deciding the size of bearings has been that the product of the speed by the pressure should not exceed a certain figure, but it is doubtful whether this rule is of much value, as it really assumes greasy friction and not perfect lubrication. In land work a product of 5,600 has rarely been exceeded or 75lbs. per square inch at 75ft. per second. At lower speeds, higher pressures are used satisfactorily, as, for example, at about 35ft. per second a pressure of 130lbs. to 150lbs. per square inch is admissible.

In a discussion on Prof. Christie's paper before the American Society of Mechanical Engineers in 1912, Hodgkin-

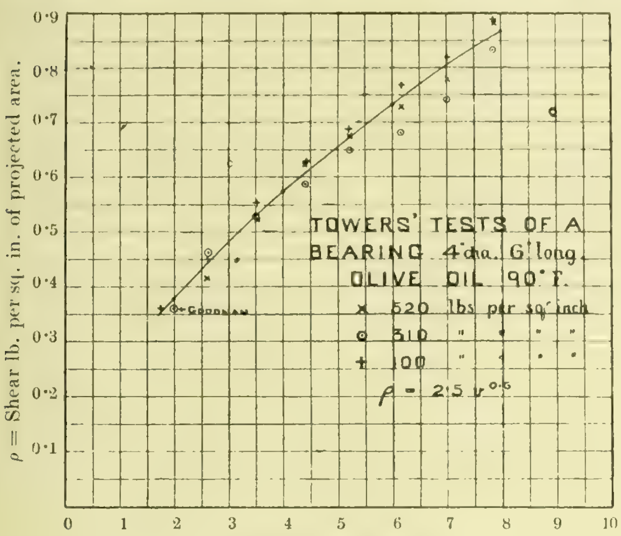


FIG. 3.

son stated that speeds of 80ft. per second and 100lbs. per square inch were commonly employed in America, and where there is no risk of heavy vibration there does not seem any reason why higher pressures should not be used. It has to be remembered that the heat to be carried off does not increase with the pressure, and that the real danger lies in the possible breaking down the oil film by excessive pressure or vibration.

In marine turbines the journal speeds are much lower than on land and rarely exceed 30ft. per second, and the pressures are usually 80lbs. to 100lbs. per square inch, but there is a strong tendency to increase this latter figure, and it is probable that pressures of 150lbs. or even possibly 200lbs. per square inch could be used, especially if the oil temperature does not exceed 100° to 110° Fah., as is usual in marine work.

The temperature of the oil is limited by its loss of viscosity at high temperature (see Fig. 4), and by its liability to carbonise and oxidise and thus cause deposit in the pipes, oilways, &c. In land practice temperatures of 120° to 140° Fah. are common, but it is not well to go above 150° or 160° Fah., as most oils seem liable to oxidise and cause deposit above this temperature. At about 250° Fah. most oils cease to lubricate, as their viscosity becomes too low.

Lasche's tests show that the friction is approximately inversely proportional to the temperature measured from freezing point, but after a certain temperature the friction rapidly increases and seizing takes place, due to the loss of viscosity. In all high-speed bearings artificial means have to be used to carry off the heat, radiation from the bearings not being sufficient. The general plan is to have such a flow of oil through the bearing as to cause the heat generated to be carried away without an undue rise of temperature. Water-jacketing the bearings has been used in some cases, but it is not as satisfactory in general as the plan of supplying sufficient oil to carry off the heat. Oil coolers have therefore generally to be provided to cool the oil.

In some cases also the oil is circulated round the outside of the bearing in suitable passages so as to assist in cooling it, and this is probably necessary in the case of very large bearings running at high surface speeds. The heat to be removed is not only that caused by friction, but also that caused by conduction from the steam; on the other hand the bearings near the condenser are cooled by the exhaust steam and heated by the gland steam. From Lasche's tests the heat produced in bearings running at a temperature of about 122° Fah. is that due to a shear of the oil film of about 0·46lb. per square inch of the projected area, and this gives us the B.T.U. per hour.

B.T.U. = 2·1 $d.l.v.$

where d is diameter of bearing in inches.
l is length of bearing in inches.
v is surface velocity in feet per second.

The constant varying inversely as the temperature above freezing point. A formula which has been often used in marine practice is: B.T.U. $= d.l.v.^{1·38}$, which gives slightly greater results for the usual speeds in marine work and an oil temperature of about 100° Fah. It may be taken that this is approximately the heat that has to be carried off by the oil. Taking the specific heat of oil to be 0·31 and allowing a rise of 10° Fah. in the oil, we require 20lbs. or about one-third of a cubic foot of oil per hour per square inch of projected bearing surface when the surface speed is 30ft. per second and 40lbs. or two-thirds of a cubic foot of oil per hour with a surface speed of 60ft. per second. In practice these quantities are often increased by from 30 to 50 per cent. to allow of the unequal distribution of oil between the bearings and to ensure that there is no undue heating, also in some cases to allow for the flow of heat from the steam.

Ring lubrication was experimented on by Lasche, but the results were found to be very variable, and in general he says that the tests show ring lubrication to be very uncertain, and that it should not be used in cases where external cooling of the oil is necessary.

Thrust bearings are generally of the usual collar type, with the bottom and top halves separately adjustable to take up end play, and in land turbines, which are practically balanced, the pressures are very low, never exceeding 20lbs. per square inch, and even in marine turbines 50lbs. per square inch is never exceeded. There are no tests available as to the friction of such bearings, but it is probable that it is fairly high, as perfect lubrication is difficult to attain, and as an approximation the total area, that is, the area of the top and bottom halves together, might be added to that of the main bearings in estimating the quantity of oil required and the surface of the oil cooler. Such bearings have generally a high coefficient of friction, owing to the low pressures employed, since, as it is impossible for a wedging action to take place and thus admit the oil, such as has been described as occurring in the case of journal bearings, the lubrication is rarely perfect. Towers found at moderate speeds that the pressure which could be safely carried was about 60lbs. per square inch, as against 600lbs. in a journal bearing, and that the shear resistance of the oil film was greater, being 1·5lbs. per square inch, this

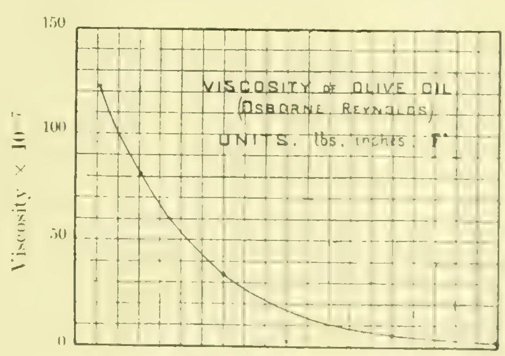


FIG. 4

giving about 16 times the coefficient of friction for a thrust bearing as for a journal one.

The theoretical consideration of the conditions necessary for perfect lubrication as set out in Osborne Reynolds' Royal Society paper in 1886, referred to above, and also his own investigations, led Michell in 1905 to devise a thrust bearing which would admit of perfect lubrication (see patents 875 of 1905 and 8,885 of 1912). In this thrust bearing there are segmental blocks pivoted at the theoretical centre of pressure, which is about 0·6 of the length from the leading edge. By this device perfect lubrication is attained and pressures up to 1,500lbs. per square inch can be safely carried at high velocities, with a consequent reduction of the coefficient of friction to about $\frac{1}{60}$th of what it is in an ordinary thrust

bearing. Another advantage is that the end play in the thrust bearing can be greatly reduced. The same idea has been further developed by Sir Charles Parsons, K.C.B., F.R.S., in patent 8,266 of 1912, where the blocks are centrally pivoted, and it has been found that in cases where the pressure comes on gradually this works equally well in practice, and has the advantage that the shaft may run in either direction without the complication of shifting the point of support.

These principles have also been applied to journal bearings by Michell (patent 23,496 of 1911) and Sir Charles Parsons (patents 8,266 of 1912, 29,810 of 1912, 953 of 1913, and 5,619 of 1913), enabling greatly increased pressures to be used, with a resultant reduction of the coefficient of friction and also a large reduction in the length of the bearings, and thus of the whole plant. The reduction of friction may in some cases bearing may be from 0·0008 to 0·003, and for such a pressure as 500lbs. per square inch may be safely taken as about 0·002, or, say, one-tenth to one-fifteenth of that of an ordinary thrust bearing.

The Westinghouse Company of Pittsburg made an interesting set of tests on such a thrust bearing for a steam turbine, the pressure being varied by throttling the balancing pipe to the dummy piston. The following are the particulars of this bearing:—

Outside diameter of collar	$4\frac{3}{4}$in.
Inside diameter of collar	$2\frac{7}{8}$in.
Number of pivoted blocks	10
Total area of pivoted blocks	10·4 sq. in.
Revolutions per minute	3,470
Mean surface speed	54ft. per second.

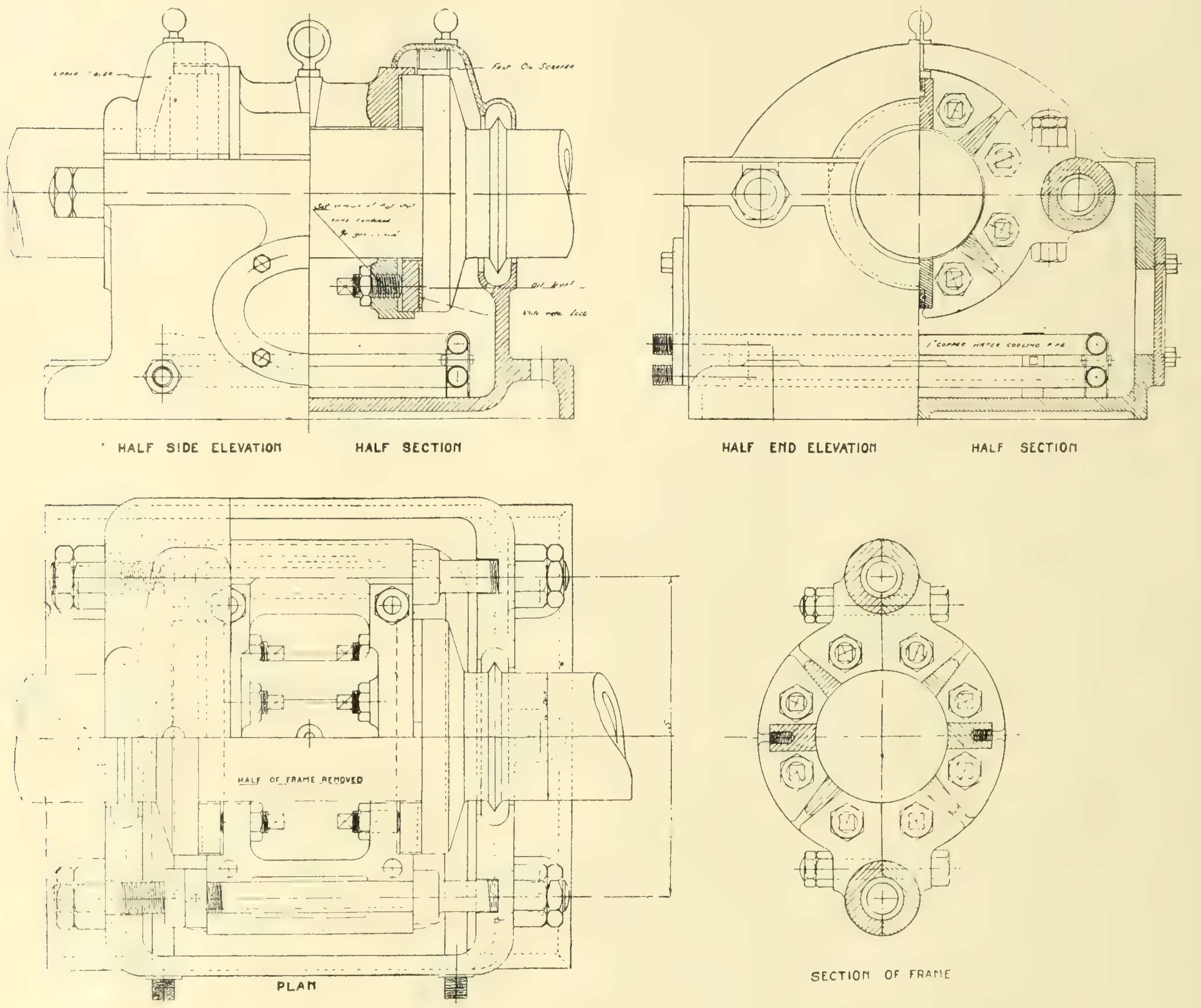


FIG. 5.

reduce the consumption of steam between 1 and 2 per cent. in a turbine plant. Ferranti (patent 5,035 of 1910) has also worked on the same lines, as well as Kingsbury in America (American patent 947,242 of 1910), and there are full details of the latter's thrust bearing in the "Journal of the American Society of Naval Engineers," November, 1912. Fig. 5 shows a thrust bearing of the Michell type designed by Mr. H. T. Newbigin for 23,000lbs. thrust at 550 to 570 revs. per minute.

In the U.S.S. "Neptune" a single collar $13\frac{1}{2}$in. diam. carries 45,000lbs. thrust at 72ft. per second mean speed surface, or a pressure of 500lbs. per square inch, and in general, such turbine thrust bearings are designed for about 500lbs. per square inch at 60ft. to 75ft. per second. Much higher pressures can be safely carried, as is shown by some tests carried out by the Westinghouse Company, where pressures up to about 7,000lbs. per square inch at 54ft. per second were carried without heating. The coefficient of friction of such a

The blocks were steel faced with white metal $\frac{1}{16}$in. thick, and were pivoted behind their centre of area, and, with all the blocks in use, 1,010lbs. per square inch was carried without heating. As this was the limit of force which could be applied, the number was first reduced to four blocks, and then to two, the corresponding pressures per square inch being respectively 2,620lbs. and 5,420lbs. per square inch, which were carried without difficulty. The surface was then reduced to 1·9 sq. in. and the pressure rose to 5,910lbs. per square inch. It was further reduced to 1·2 sq. in. with a pressure of 10,000lbs. per square inch, but here the white metal flowed in all directions until the area was increased so that the pressure was reduced to 7,000lbs. per square inch, but no heating occurred.

It is worth noting that the white metal flowed equally in all directions, irrespective of the direction of rotation. It is thus seen that the limit of pressure with such a bearing is the

flowing of the white metal and not the failure of the lubrication, and that with pressures of 500lbs. per square inch there is an enormous margin of safety, and it is probable that three times this pressure will be found quite safe in practice.

THE USE OF DRY AIR IN THE BLASTFURNACE.*

BY H. G. GIRVIN.

THE average amount of moisture in the air at our Hamilton Works, where the dry blast plant is located, was 3·152 grains per cubic foot for the year 1912, and slightly higher for 1913, about 3·25 grains per cubic foot. These data are obtained by averaging hourly determinations during the whole year. Assuming a daily average content of 3·152 grains of moisture per cubic foot and 50,000 cub. ft. of air per minute, we find that we are blowing into our furnaces a little more than 16 tons of water vapour in 24 hours. Of course, in the summer months the moisture contained in the air is much higher than in the winter time, and we frequently extract as much as 33 to 35 tons of water in one day. Our best record has been the extraction of 39·9 tons in 24 hours. Briefly, our system is to reduce the temperature of the air to 32° Fah. by means of cooled brine, and then to cool the air further to from 0° to 5° Fah. In the summer about two-thirds of the moisture is extracted in the first stage of the process, and in the second stage the percentage of moisture can be reduced to any desired limit. The following is a description of the units in the dry-blast system, as installed at the Hamilton Works of the Steel Company of Canada, Ltd.

The compression side of this plant consists of three horizontal machines, twin cross-compound type (De La Vergne pattern). Each machine has one high-pressure horizontal steam cylinder 24in. diam. and 33in. stroke, and one low-pressure horizontal steam cylinder 48in. diam. and 33in. stroke, with long-range Corliss automatic cut-off and governor. The high-pressure side is designed to withstand a pressure of 150lbs., and the low side a pressure of 50lbs. per square inch above the atmosphere with safety and without undue heating.

The engines will work the compressors with maximum economy at normal speed of 65 revs. per minute under the following conditions: Discharge pressure, 150lbs. per square inch above atmosphere; suction, 17lbs. per square inch above atmosphere; steam, 125lbs. per square inch above atmosphere; vacuum, 24in. mercury in exhaust pipe.

When running non-condensing the engines will make 65 revs. per minute under the following conditions: Discharge pressure, 190lbs. per square inch above atmosphere; suction, 17lbs. per square inch above atmosphere; steam, 90lbs. per square inch above atmosphere.

The ammonia compressors have a refrigerating capacity of 300 tons each under the above conditions, and consist of two water-jacketed horizontal double-acting compressors 18¼in. diam. and 33in. stroke; they have been tested to a hydrostatic pressure of 500lbs. per square inch and are absolutely gas tight. The ammonia condensers (De La Vergne type) are of the double-pipe surface-condensing variety, consisting of 78 stands containing 12 double pipes each, and are arranged and connected in three units, each having 26 stands, the pipes being 2in. and 1¼in. respectively. The total weight of these condensers is 125,400lbs., and the total effective cooling surface is 6,270 sq. ft. This, of course, represents the outer surface of the 1¼in. pipe, as the 2in. pipe carries the ammonia.

The ammonia condensers are of sufficient size to condense enough ammonia to cool 1,908 U.S. gallons of brine per minute from 17° Fah. to 7° Fah., when working in connection with the other units and with condensing water at a temperature of 80° Fah. and a condensing pressure of 190lbs. per square inch. This is equivalent to 678 refrigerative tons per 24 hours.

The ammonia receivers, of which there are six, are made of wrought iron, each being 12ft. long and 15in. diam., tested to 1,000lbs. pressure. They are horizontal, and receive the ammonia from the condensers. There it is carried into the bottom of the brine coolers, which are large insulated tanks containing the brine coils. The liquid ammonia is passed in through an expansion valve and the tank is filled to within about a foot of the top. The compressor pumps the gasified ammonia from the top of these tanks at a pressure of 17lbs. (gauge pressure) and delivers it to the condensers again, still in the form of gas, at a pressure from 100lbs. to 190lbs., thereby making a complete cycle.

The brine coolers are of the Isbell Porter shell type and are four in number, each with a riveted steel shell 59in. diam. and 12ft. long, closed with cast iron dished heads and supported on cast iron columns. Each cooler has sufficient 1¼in., 1½in., and 2in. double wound pipe coils of extra heavy wrought-iron pipe to aggregate a cooling surface of about 10,000 sq. ft. for the four coolers. Each coil projects through stuffing-boxes well secured at each end, and assembled in junction boxes at the top and bottom. All coolers are thoroughly insulated. They have sufficient capacity to cool 1,908 U.S. gallons of brine per minute from 17° Fah. to 7° Fah. when operating with other parts of the refrigerating apparatus with ammonia suction pressure of 17lbs. per square inch. The total weight of the four coolers is 145,000lbs., and the brine referred to is calcium chloride brine with a specific gravity of 1·21 and a specific heat of 0·70.

To circulate the brine we have four steam pumps. Three of these are of the cross-compound crank and flywheel type with a capacity of 700 galls. per minute each, and the fourth one is of the duplex compound type, with a capacity of 1,000 galls. per minute. We also have two fans, one at each end of the building, to draw the outside air into the building and over the brine coils at a slight increase in pressure. These are driven by vertical steam engines, and each fan has a capacity of 40,000 cub. ft. per minute.

The brine pumps force the brine through the coils in the brine coolers, where it is cooled by the evaporating ammonia to the temperature required, and then to the brine coils in the refrigerating room proper where these are located. The pipes in this part of the building are made of 2in. lap-welded iron pipe, each length of pipe 20ft. long plus the return bends, and if placed in one line would stretch 40 miles. These pipes have a cooling surface of 132,000 sq. ft.

The oiling system in connection with these machines is of the gravity feed type, with water separators and Burt filters. This plant has run on 40 galls. of engine oil for over 13 months, and will easily exceed this record.

The air, which has now passed completely through the system, is delivered to the blowing engines at a moisture content of about 0·85 grain per cubic foot, and a temperature of about 20° Fah. Both temperature and water vapour can be controlled to a nicety, thereby eliminating the one great variable in the running of blastfurnaces.

We find in practice that the actual saving in fuel is far greater than can be shown by calculation. This may be accounted for in several ways. The temperature of the top gases is greatly reduced, the loss of stock in the form of flue dust is materially lessened, and figuring per unit of production the amount of coke, stone, and air charged is much less; therefore the capacity of the stoves, blowing engines, &c., is correspondingly increased, and the working capacity of the furnace is also increased, giving a greater production. According to our records, we are producing more iron with less coke consumption than we did when running under the conditions of natural air. I have taken averages for a whole year in each case, and for the sake of comparison have used the records showing the best results during the last six years, for a single year under both dry and natural blast.

On basic iron our furnace A produced in 1913 about 16 per cent. more iron with 12 per cent. less coke than it did in 1907, which was the best year under natural blast; and our furnace B, making foundry iron, produced 22·3 per cent. more iron in 1913 with 2·7 per cent. less coke than in 1908, which was the best year under natural blast.

One peculiar factor in the dry blast plant is that occasionally in winter, when the temperature falls to, say, 10° or 15° below zero, the moisture in the outside air is lower than we require, and, therefore, as we prefer to have a constant rather than an extremely low moisture content, we sometimes run the dry blast plant backwards, and add to the original percentage of moisture. Ordinarily we keep the moisture content in the dried air uniformly between 0·80 and 0·90 grain per cubic foot. For instance, on February 12, 1911, the temperature of the outside air was 5° Fah. below zero and the moisture content was 0·2 grain per cubic foot. This air was delivered to the furnace at a temperature of 11·2° Fah. with moisture at 0·76 grain. To do this it was necessary to

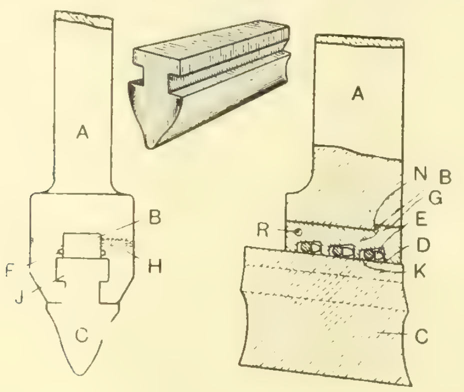
* Paper read before the Canadian section of the Society of Chemical Industry.

add to the blast 5,557lbs. of moisture in the 24 hours. This was accomplished by passing 10 per cent. of the first-stage brine circulation through a closed coil steam heater and keeping the first-stage brine at a temperature of 20° Fah. Cold dry air from the outside was warmed in passing the first-stage coils and rapidly absorbed moisture by sublimation of the snow on the second-stage coils. Regulation of the moisture can be effected in this manner as long as any snow remains on the second-stage coils.

Thus, as the records show, there has been a general improvement in amount of product, also from cast to cast the chemical composition of the metal produced is more uniform, and, lastly, this has been accomplished with less fuel per ton of product under the conditions of dry blast as compared with that of natural air.

TOOL AND TOOL HOLDER FOR LATHES.

THE accompanying illustrations show a novel design of tool holder and cutter for lathes and other machine tools, the joint invention of Mr. D. Richards, 165, Bexley Road, Northumberland Heath, Belvedere, Kent, Mr. H. R. Grayson, and Mr. C. L. E. Melsom. J is a parallel slot at the end of tool holder A, in which slot is mounted the tool C together with the hardened roller casing B which is recessed with a series of inclined transverse grooves K, in each of which is mounted a roller D and a flat bent spring E with V-pointed ends. On either side of the slot J is a small V-groove F in which the reduced ends of the rollers D and springs E move freely, these grooves being provided in order



TOOL HOLDER FOR LATHES.

to prevent the displacement of the rollers and springs. The springs E press the rollers D towards the narrow ends of their slots and consequently into contact with the back of the tool C. At the back of slot J is a semi-circular recess N for the reception of the corresponding projection G at the back of the casing B, which recess and projection, together with the grub screws H, taking into the holes or recesses R, hold the race in position. The rollers D are adapted to move freely in the grooves K, and the springs E act on the rollers D in such a manner as to force the latter towards the narrow ends of slots K and against the back of the tool C, thereby locking the tool against the pressure of the work. The tool C can only be removed from the holder in one direction—that is, from back to front; while the tool can only be inserted from the back.

The Junior Institution of Engineers: North-western Section.—A meeting of this Section was held at the Municipal School of Technology, Manchester, on the 17th inst., when a paper was read by Mr. J. H. Lester, M.Sc., on "Motor-cars Ancient and Modern." The author described some of the earliest known types of autocars, and commented on the retrograde effect of the Act of Parliament limiting their speed to walking pace. Afterwards various designs of modern cars were explained and criticised, high tribute being paid to Lanchester for his scientific pioneering. Carburetter troubles were dealt with at some length, and gear boxes forcibly dilated upon from a true engineering standpoint. A number of lantern slides were exhibited, enabling the author to demonstrate his points very lucidly.

LIGHTNING CONDUCTORS AND THEIR TESTS.*

BY F. H. TAYLOR.

THE generally accepted opinion is that lightning discharges are of two distinct kinds, named by Sir Oliver Lodge the "A" flash and the "B" flash respectively. The "A" flash is simple in character and consists of a discharge between an electrically-charged cloud which is approaching the surface of the earth without any intermediate cloud intervening. The path of the "A" flash is more or less prepared by the electrostatic conditions of the case, and it is said to strike pointed conductors in preference to others. The "B" flash is a disruptive discharge of great suddenness, and arises where another cloud intervenes between the cloud carrying the primary charge and earth, the two clouds acting like a condenser. The Lightning Research Committee of 1905 reported that "when a discharge from the upper cloud takes place into the lower cloud the free charge on the earth side of the lower cloud is suddenly relieved, and that the disruptive discharge from this to the earth takes such an erratic course that no series of lightning conductors of the then hitherto recognised type suffice to protect the building." It should be noticed that flashes of the simple "A" type are subject to what I would call "splashes," or, as some authorities call them, "lateral discharges." In a case I know of in South Africa, the veranda (or as it is there called the "Stoep") has several electric light cord pendants. These are continually failing. This failure is not due to attack by rain or moisture, but my own feeling is that miniature lightning discharges are responsible.

Lightning discharges are sometimes quite silent, and being so may pass unobserved. I well remember some overhead electric lighting conductors erected under my supervision in the grounds of a building placed on very high ground on the outskirts of one of our home counties. I had lightning arresters attached to these where they entered the premises. Curiously enough, during the first summer, although several severe storms occurred, nothing observable happened. During the second summer, however, when everyone agreed that no storms had been noticed, one after another my lightning arresters gave evidence of having received discharges—apparently silent ones. Lightning is stated by many authorities to act like weak human nature, and to select the path of least resistance. But what forms the path of least resistance—the lightning alone decides.

Protection against the "A" type of flash is fairly easy, and it is considered that the ordinary system of conductors, when properly constructed and maintained, is reasonably safe. Discharges of the "B" type involve more complex treatment, and in the words of the Lightning Research Committee, 1901-5, "absolute protection can only be assured by a complete wirework enclosure, in fact, of the nature of a bird cage." In any case, the extent to which a building shall be protected and the cost of such protection usually has to bear a certain relation to the importance and the first cost of the building itself. Unfortunately, the lightning-conductor work of most buildings is treated with an indifference as dangerous as it is unjustifiable. The specification for a building costing, perhaps, £10,000 to £12,000 will sometimes dismiss the whole matter by merely stating "allow £10 per cent. value for lightning conductor." With such a delightful amount of detailed description it is not surprising that any sort of job forms that so-called lightning-conductor system—often put up by people quite ignorant of the work, and utterly careless of the possible consequences of their ignorance. It is indeed regrettable that insurance companies have not so far, by united action, found it possible to insist upon both adequate protection and maintenance. A public building which cost £125,000 to erect came under my care. On examining and testing the lightning conductors I found each

* Abstract of paper read before the Junior Institution of Engineers, March 13th, 1914.

one absolutely useless as well as being a definite source of danger.

Briefly put, any lightning-conductor system comprises: (1) The air terminal, consisting of what is called the "elevation rod," the top of which is provided with one, three, four, or even five points; (2) the conductor, from the elevation rod to the ground, with branch conductors from other parts of the building, or from the metal work of the structure, such as gutters, stack-pipes, metal roofing, &c; and (3) the earth connection.

The metal most commonly, in fact, almost universally, used is copper, in the form of copper tape from, say, $1\frac{1}{2}$in. by $\frac{1}{8}$in., down to $\frac{1}{2}$in. by $\frac{1}{8}$in. Iron is electrically efficient, but is more subject to corrosion and not so easily fitted into position. As to the design of the conductor system, this can only be settled when the design of the building, including its chimneys, turrets, gables, ridges, roofing material, &c., is known, and some consideration must also be had for its general situation. For rough guidance, however, a few general first principles may here be given: (1) Conductors should run in as direct a line to earth as possible. Some persons prefer to keep them a certain distance from the wall. This has the advantages of avoiding an accumulation of dirt and also avoiding sharp bends when crossing over cornices, &c. (2) Vertical rods should preferably be connected by horizontal conductors fixed to ridges or other suitable part. (3) Roof metal-work, &c., should be connected to the system. (4) Chimneys should be protected as being specially liable to be struck, owing, of course, to the column of hot gases which are good conductors, the carbon lining to the chimney in the form of soot and the mass of metalwork at the base, in the form of a stove. (5) Any joints in conductors should be both soldered and screwed together. (6) Conductors should be kept as much away from interior gas pipes or electric pipes, &c., as possible. (7) Similar metals should be used throughout, *i.e.*, the holdfasts should be of gun metal, and screws or rivets, &c., of copper. (8) Long runs along ridges, &c., should preferably have more than one elevation rod, say, at least one at each end, several short points along a ridge being better than a few tall ones.

The earth connection of any lightning-conductor system, however simple that system may be, is of the very utmost importance, and if it be inefficient the whole system may be regarded more as a danger than as a protection. The matter of obtaining a good earth connection is mainly a question of surface contact between the conductor and moist earth. A moderate amount of resistance (ohmic resistance) is not harmful, in fact may be otherwise. The mere fact of taking the conductor into moist earth, or even into water, does not necessarily form a good earth connection unless there is a considerable area of contact. The usual method of forming an earth connection is by means of a copper plate. The thickness is not important provided it is sufficient to withstand oxidisation. A plate measuring 30in. by 30in. by $\frac{1}{16}$in. would be more efficacious than one 12in. by 12in. by $\frac{1}{2}$in., although the latter gives 72 cub. in. of copper as against 56 cub. in. of the former. The copper tape conductor should be well connected to the plate, preferably riveted as well as soldered, and the soldered joint pointed over to retard electrolytic action. Many people bury the plate horizontally; personally, I always make the interment vertically. The earth connection should always be kept well away from the building and also well away from gas mains.

It is absolutely necessary that the earth connection should be kept fairly moist so as to allow the resistance to remain moderate in value. It is usual to bury a quantity of broken coke or cinders with the plate, with a view to retaining the moisture. If either material be used it must be thoroughly washed so as to get rid of any sulphur present which would destroy the copper. There are, of course, cases which sometimes arise where to bury a copper plate in the ground is to invite certain failure. In the neighbourhood of certain factories (tar or creosoting works, &c.) the soil is found saturated with ammonia, which is destructive to copper.

To facilitate discharge into the general mass of earth sawtooth points to the plate are sometimes used. A special type of earthing plate adopted by the London County Council is to the following specification: "To be of copper $\frac{1}{16}$in. S.W.G. tape riveted and soldered the full length of the plate, joints washed of acid and protected by thick coat of tar. Each plate to have four rows of triangular tongues formed out of the plate itself—two rows of six and three inner rows of five each, so that tips of tongues in adjacent rows point in opposite direction, each tongue being 3in. long and tapering from 2in. to a point. Tongues to be bent at right angles and to point upwards when the earth-plates are laid in position." The loose earth or wood charcoal to be filled in and well rammed on top of the plate. This plate possesses the characteristics of the one proposed by Sir Oliver Lodge in connection with Elan Valley Waterworks.

The difficulty of keeping the earth connection moist is in some cases a very real one—of course, if a pond, lake, or river can be utilised it is excellent, provided the plate is kept free from mechanical injury, and that you do not one day find yourself with only the end of the tape left. In order to facilitate the provision of a proper earth terminal the patent tubular earth has been designed by Mr. Killingworth Hedges, M.Inst.C.E., M.I.E.E. This mainly consists of three parts; the upper for connecting to the copper tape or cable, and also to a rain-water pipe; the lower end, which forms the actual earth and which is fitted with a steel spike for driving into the soil, and a removal cap for marking the position of the earth in the ground.

It not infrequently happens that the earth-plate originally installed on a job has failed, and that for various reasons another cannot be sunk. In this case a live water-main makes an excellent and a lasting earth contact, care being taken, of course, that the connection between the tape and the pipe is properly made. Such connection will, of course, be external to the building.

The inspection and testing of a lightning conductor after it has once been installed is mostly conspicuous by its absence, and this is undoubtedly the cause why accidents from lightning are often reported to have occurred to buildings that have been believed to be protected by conductors. It is not simply a case of "out of sight—out of mind." It is open neglect. The reasons which call for regular inspection and test are obvious. The air terminals are the most exposed part of the structure and acted on by wind and weather, and additionally, in towns, by uncertain and corrosive impurities in the air; the air terminals cannot be made unduly large without being unsightly; very acute bends in the tape are often most wrongly insisted upon—purely for the sake of appearance—which seems to count for more than safety; decay of the earth-plate may arise when least suspected, and particularly disconnection just above the ground line. The tests which should be made should show the conductor to be continuous from air to earth, and to possess a sufficient lowness of resistance to earth, so that it may be considered reasonably safe for conducting away a discharge into the earth.

Methods of testing I will divide under two heads: (*a*) The bell test, which merely shows continuity or otherwise; and (*b*) measurement of resistance test. The first method is of little or no service whatever, though it is useful as a preliminary. The measurement of resistance is mostly made by some form of Wheatstone bridge, the most usual, perhaps, being an ordinary P.O. bridge worked with a few dry cells. People who only test jobs situated right out in the open country swear by this method. If they had to test in a very congested town district, as, for instance, in some parts of London, they would then swear at it. The prevalence of "earth currents," due to countless telephone and similar circuits, has, within my experience, made this type of apparatus very troublesome, and in some cases impossible to work with. A modification of this apparatus is the "Magneto-inductor Bridge," manufactured by Siemens Bros. & Co., Ltd. Another method I have used with great success in congested districts infested with earth currents is to pass a good current (measured) through the conductor and earth, and, observing the drop in volts, calculate the resistance from the known quantities. For this purpose I have used a 4-volt accumulator good enough for any discharge up to, say, 60 or 70 amperes. In this way you can readily obliterate other people's earth-currents, and thus carry out reliable tests.

THE USE OF SUPERHEATERS AND SUPERHEATED STEAM IN MERCANTILE STEAMERS.*

BY HARRY GRAY.

THE re-introduction of superheaters in boilers, and the use of superheated steam in engines of the mercantile marine, has been brought about by continuous research together with costly experiments, by the greater knowledge obtained in the process of making and amalgamating metals, by the improvements in the manufacture of such metals into tubes and other suitable forms, by the introduction of oxy-acetylene and electric welding, by the preparation of lubricating oils for use under high temperatures, together with a mass of data, the result of years of experimenting and investigation, and which has now been put to the crucial test of practical working.

Superheaters, when introduced into marine boilers some 70 years ago, developed rapid deterioration, producing such a heavy bill for repairs and renewals that they were regarded as too costly, not to say dangerous, for use on board a steamer, and it is possible that the experiences and the troubles which then developed have contributed to the extreme caution exhibited by many engineers and steamship owners in considering the pros and cons of the use of superheaters and superheated steam to-day. In the "Mechanics' Magazine" of April, 1861, appears an article on "Superheated Steam," which is a most interesting record of what may be considered the last serious effort to give a superheat to steam for use in steamers, and the following extracts are taken therefrom:—

"Mr. Thomas Howard is credited with establishing the fact that great economy might be effected by the principles of superheating in about the year 1833, and that Dr. Haycroft shortly afterwards urged its application on the ground that it would effect a saving of 30 per cent. in fuel.

"The 'Prince Alfred,' of 200 h.p., belonging to the Inter-Colonial Royal Mail Company, is stated as being 'the first sea-going vessel working with unmixed superheated steam and fitted with Partridge's system.'

"Other vessels mentioned are the 'Damascus,' of 200 h.p., the consumption per indicated horse-power being reduced to 3lbs. In the Tyne a vessel of 400 h.p. was fitted, and 'it was found very beneficial during a voyage from Southampton to Rio de Janeiro and back.' The H.M.S. 'Dee' was fitted, and after four years was reported as in good condition.

"Altogether 50 vessels were fitted with 'Partridge's' apparatus, representing 10,000 h.p. to 12,000 h.p., and the savings effected by the use varied from 15 to 30 per cent. In general, the steam was superheated to about 340°, and the pressure ranged from 10lbs. to 25lbs. per square inch.

"Other superheating apparatus mentioned are those of 'Parsons' and 'Pilgrims,' fitted on the 'Osprey' in 1859, also H.M.S. tug 'Bustler' in 1859, and in 15 other vessels. Lamb's superheater, patented in 1858, was adapted to over 50 vessels with a saving of 20 to 40 per cent. Messrs. Boden and Clarke's superheaters were fitted on the 'Southampton' in 1860, trading between Southampton and Channel Islands, of 262 h.p. condensing engines with two slide oscillating 60in. cylinders, 5ft. stroke. She burnt only 37 tons on each trip out and in, averaging 22 hours, or about 12lbs. per horse-power. The 'Dispatch' was also fitted. Butler's superheater was fitted to the 'City of Nantes,' with a saving of 30 per cent. and increased speed. Pullen, Cresswell, and Longstaff's apparatus, patented in 1860, and many others which showed equally favourable results. Reference is also made to the researches of Dr. Taylor, Mr. Brande, Prof. Faraday, Mr. Fairbain, and others."

Messrs. J. & W. Dudgeon, of Millwall, between 1859 and 1870 fitted about 40 vessels with Beardmore's system of superheat.

The steam engine being essentially a heat engine, no excuse is needed for advocating the use of superheat; if such were the case, however, the records of the past 70 years alone are full of instances of the devices brought out for steam jacketing, reheating, and other arrangements for retaining and maintaining the temperature in the cylinders. The drop in the temperature, not only between the boilers and the engines but also in the cylinders themselves, beyond that due to the expansion of steam, has been, if not the greatest, at least one important cause of loss of power in steam engines, as it has thereby increased the amount of saturation in the steam.

Another loss arose from the amount of saturation brought over by the steam from the boilers, when priming was not violently taking place. This loss is seen more or less in all marine engines by the quantity of water which comes down through the piston-rod glands, to the detriment of the packing and the piston rods. It is also manifest by the noise which betrays the presence of water in the cylinders, although there may be none of the usual evidence of priming in the boilers, which shows that whilst a small percentage might be attributed to condensation in the cylinders, a large volume is really due to the heavy state of saturation of the steam coming from the boilers, and moreover that this is a variable quantity, due no doubt to the conditions of firing, circulation, or the quality of fuel.

In order to obtain some data bearing upon this loss, measurements were taken of the water coming from the cylinders of quadruple-expansion engines of 3,000 i.h.p. working under saturated steam conditions, readings being taken during the voyage, and at times it was found that as much as 20 galls. per hour was drained off the M.P. 2 and L.P. steam chests. The fact that such a quantity of water was found to accumulate in the cylinders of a quadruple-expansion engine, working under saturated steam conditions, convinced Mr. Alex. J. Dudgeon and the writer that superheat would convert this loss into effective horse-power and so contribute to a more economical result.

The modern system of superheating steam passes the saturated steam from the boiler through small tubes placed in different positions, according to the type of boiler, whether water-tube or marine cylindrical multitubular, usually termed the "Scotch" boiler. It is not proposed to deal with the various points of interest regarding the different types or design of superheaters which naturally arise, but which do not come within the scope of this paper, which is confined to the experience of the use of superheat on steamers, with special reference to the important question of economy and cost of upkeep, based on over three years' working in engines of both triple and quadruple-expansion type in the mercantile marine engaged in a regular trade, voyage after voyage, to Australia viâ the Cape of Good Hope.

In the system adopted (Schmidt's) the steam from the boilers passes into a vertical pipe called the "saturated" header placed in the smokebox, from which small branch pipes are led horizontally across the front of the tube plates, the pipes passing down each tube of the row being doubled in a "U" form for that purpose, so that each "element," as it is termed, is a series of "U's," the other end being brought back to what is termed the "superheated" header. The jointing of each end of the element to the headers is effected by a small cross-bar or "dog" with a stud through the centre, so that each dog makes two joints. Careful supervision, testing, and tightening up, as the pressure rises when getting up steam, prevents any leakages afterwards, as when once tight they do not give further trouble. A drain is fitted to both headers, that on the saturated header for blowing away any scum that might be brought over from the boiler, and which would possibly choke the lower rows of elements, and a drain on the superheated header to permit of a circulation of steam through the elements when getting up steam, or when the steam is not being circulated in consequence of the supply to the engines being shut off whilst working the engines to orders in ports.

The elements are examined periodically, being removed from each nest of tubes in rotation, so many each voyage, thus all are dealt with at least once a year; but whenever the boilers are cleaned the ends of the elements are examined from the combustion chamber, as they are only about 9in. inside from the back tube plates, for any signs of leakage at the weld of the U bend of the elements. These defects are something less than ·1 per cent. and are generally only pin-holes. Even should it be necessary to deal with the U end. it is not a serious matter, either in time or expense, and, in the event of a serious leak, the steam from the boiler can be shut off the superheater and by-passed direct to the engines, whilst the defective element is withdrawn and the

* Paper read at the spring meetings of the fifty-fifth session of the Institution of Naval Architects, April 2nd, 1914

joints on headers remade with blank plugs, the gross area through the elements allowing for a considerable reduction without unduly wire-drawing the superheated steam. Experience has shown no deterioration of the elements from corrosion or burning of the end, or any injurious action on the boiler tubes. The chief expense incurred with superheat is on account of extra labour when withdrawing these elements for inspection. None of the steamers under consideration have been delayed either in port or on the voyage from defects in superheater elements since being fitted, notwithstanding the fact that they are turned round quickly and have long runs, that of the "Port Augusta" being 45 days without a call at any port, and the "Port Lincoln" and "Port Macquarie" 39 days, with a call of a few hours only at Capetown for coal and fresh water. The cleaning of the tubes on the voyage is effected by "Diamond Blowers" fitted in each combustion chamber, and they are blown through every day, the operation taking about two or three minutes for each nest, the soot which accumulates in the smokebox being cleared away through the doors provided for the purpose.

The absence of moisture, upon which marine engines rely for internal lubrication, makes the lubrication of the cylinders and valve faces of most vital importance when superheated steam is used. In the first instance, an excess of internal lubrication is advisable, until the pores of the metal surfaces become saturated and filled up with oil. When this has taken place it will be found that, although the surface of the cylinder walls may be cleaned and wiped when they are hot, upon the metal cooling down a film of oil will be squeezed out of the pores on to the surface of the metal; when this condition has been attained the quantity of oil for internal lubrication may be reduced with safety. On the "Port Augusta," of 2,000 i.h.p., 1·5 galls. per day of cylinder oil were used at first for internal lubricating and swabbing of piston rods of both main and auxiliary engines; on the "Port Lincoln" and "Port Macquarie," of 4,000 i.h.p., about 2 galls. per day, this being gradually reduced until now only ·5 to ·75 gall. is required.

Another important detail with regard to this is that independent means of lubrication must be provided for each engine, either in the valve chest or cylinder. That for the H.P. cylinder should be on the engine side of the stop and throttle valve, otherwise the surfaces are liable to become coated with an oil deposit during a long run, and may cause them to work stiff, thereby interfering with their steam tightness when brought into use again on working the engines to orders. It is advisable to arrange for independent lubrication for the L.P. valve, as, owing to it being generally of the flat "D" type and unbalanced, the large surface, even with a low pressure upon it, gives rise to considerable friction. It has been found in triple-expansion engines, where the M.P. cylinder is placed adjoining the H.P. cylinder with short exhaust passages, that, after the surfaces become saturated with oil, the regular supply to the M.P. cylinder may be shut off, as it would appear that a sufficient quantity of the oil injected into the steam in the H.P. valve chest becomes vaporised, and is carried over to the M.P. valve chest with the exhaust. Nevertheless, in the first instance, a regular supply should be injected into the M.P. valve chest, and even when this is shut off a little extra oil should be injected from time to time, according to the evidence of the running and condition of the surface when opened up for examination.

The selection of a suitable lubricant for internal lubrication under the temperatures and conditions met with when using superheated steam is one requiring consideration. There are several oils on the market with a flash point under the open or atmospheric test of from 610° to 630° Fah., but due consideration must be given to their composition, whether an absolute mineral oil or a compound of a mineral with an animal or vegetable oil, which, it is claimed, adds to the lubricating qualities without creating troubles from carbonisation or other causes; this, however, is a doubtful point. Upon the question of the evaporation point, and also the flash point, when the oil is under pressure, we know of no reliable data; possibly these points are higher under pressure than those obtained by the tests under atmospheric conditions.

It is absolutely necessary to have a reliable system of filtration for the feed water, so as to ensure the abstraction of the oil and safeguard the boilers from the possibility of any traces getting through. The difficulties at first met with to obtain this result have been overcome by fitting a large gravitation filter. The whole secret of filtration is "time" to allow the feed water to come almost to rest, and enable the oil to rise to the surface and be collected; afterwards the feed water should pass through a chamber filled with coke, and finally through a section fitted with "cartridge" cylinders, covered with filter cloth towelling of substantial body having a rough surface. The more compartments of the first or settling stage that are provided, the longer the coke and filter-cloth sections will last without requiring to be changed. The filter must be so placed that the water will gravitate to the same water level as the weir in the hotwell of the air pumps. It is essential that the covers of this filter should be always open when working, so that it may be under observation, and that the thick scum accumulating on the surface of the settling chambers may be removed by hand from time to time. The cleaning of the coke and filter-cloth chambers can be done very quickly, if a full set of spare parts are carried, which can be kept charged with fresh coke and with clean filter cloths on, ready for use. When such spare parts are provided there is no necessity for a by-pass arrangement, as the working of the filter is not interfered with during the process of changing the filtering medium, and the time is so short that no danger from oil passing through with the feed water is experienced. The feed water betrays not the slightest sign of oil even in emulsion when drawn off from the feed pumps; there is no "taste" of oil perceptible; the internal surface of the boilers, even on the water-line, do not show any signs of oil, and this has been confirmed in each of the four boilers in both the steamers with quadruple-expansion engines having passenger certificates, upon inspection at the end of six and twelve months' service, as well as at the annual survey on the other steamer, fitted with triple-expansion engines and two boilers.

The temperature of the steam during the various stages is ascertained by pyrometers fitted to the superheater steam pipe of each boiler, to the H.P. and M.P. 1 steam chests, and by thermometers fitted in the steam chests of the M.P. 2 and L.P. engines. The general experience with the pyrometers having long connecting capillary tubes filled with ether or mercury, by means of which the temperature is recorded on the dial, shows a tendency to give unduly low readings after months of constant use, to the extent of about 5 per cent., necessitating their being frequently tested, and short connections are therefore recommended, although the position of the dials may not then be so conveniently arranged for observation. The variations in the readings of the pyrometers, due to the fluctuations of the temperature of the steam following on the condition of the fires, indicate beforehand the rise or fall of the steam pressure, and enable the engineer on watch to know in which boiler the furnace temperatures are falling, through the fires getting low or dirty, and so give the necessary orders to maintain a full steam pressure. The fitting of pyrometers and thermometers in this manner has given some very interesting information as to how far the superheat is carried through the engine—in other words, whether the temperature of the steam due to superheat falls more or less quickly than the temperature of the steam consequent upon the pressure, so as to indicate at what stage, if any, the steam loses all "superheat" and returns to the "saturated" state. Table I., which is approxi

TABLE I.

Steam Chest.	S.S. "Port Augusta." Triple-expansion Engines.				S.S. "Port Lincoln" and "Port Macquarie." Quadruple-expansion Engines.			
	Gauge pressure in steam chests.	Temp. due to steam pressure.	Temp. recorded.	Degree of superheat.	Gauge pressure in steam chests.	Temp. due to steam pressure.	Temp. recorded.	Degree of superheat.
	Lbs.	° F.	° F.	° F.	Lbs.	° F.	° F.	
High Pressure	160	370	550	180	206	389	[illegible]	[illegible]
1st Intermediate	53	300	400	100	97	335	[illegible]	[illegible]
2nd Intermediate	[illegible]	—	—	—	38	[illegible]	[illegible]	[illegible]
Low Pressure ..	10	240			9	237	220	[illegible]

mately reliable, gives the average results obtained, although the higher temperature taken by the pyrometers may, as before mentioned, be lower than was actually the case. It will be seen that superheat is showing in the steam chests of the first three engines, and almost in the L.P., while at times a few degrees of superheat are reported to have been actually registered there. The cut-offs are about: H.P., 73 per cent.; M.P. 1, 70 per cent.; M.P. 2, 70 per cent.; L.P., 70 per cent.

The steamers from which these data were obtained belong to Messrs. W. Milburn & Co., of London, and our thanks are due to Mr. Milburn for his permission to publish the results. The "Port Augusta" was built and engined by Messrs. Hawthorn, Leslie, & Co. in 1906; the boilers were fitted with superheaters, and the necessary alterations made to the engines, &c., by the North-Eastern Marine Engineering Company, Ltd., of Wallsend-on-Tyne, in May, 1911, when the boilers and engines were five years old. The "Port Lincoln" and "Port Macquarie" were built by Messrs. Hawthorn, Leslie, & Co. and engined by the North-Eastern Marine Engineering Company, Ltd., of Wallsend, in 1912. The boilers were designed for working the engines under saturated steam requirements, but fitted with superheaters. The "Port Albany" was also built by Messrs. Hawthorn, Leslie, & Co., and engined by the North-Eastern Marine Engineering Company, but the boilers were designed for and fitted with superheaters. Particulars of these four vessels are given in Table II.

Table II.

Particulars.	"Port Augusta."	"Port Lincoln."	"Port Macquarie."	"Port Albany."
Length	380ft. 6in.	425ft. 9in.	425ft. 9in.	425ft. 9in.
Breadth	49ft. 1in.	54ft.	54ft.	54ft.
Depth, moulded	28ft. 7in.	31ft. 10½in.	31ft. 10½in.	31ft. 10½in.
Gross tonnage	4,063	7,236	7,236	7,236
Deadweight	7,226	9,254	9,254	
Engines	Triple	Quadruple	Quadruple	Quadruple
Cylinders	27, 45, 74 ins.	27½, 39, 56, 81½ ins.	27½, 39, 56, 81½ ins.	27½, 39, 56, 81½ ins.
Stroke	48in.	54in.	54in.	54in.
I.H.P. on voyage	2,100	4,100	4,100	4,100
Boilers, number	Two	Four	Four	Four
Boilers, type	Cylindrical Single ended	Cylindrical Single ended	Cylindrical Single ended	Cylindrical Single ended
Total Heating Surface	5,720	11,600	11,600	11,360
Total Grate Surface	137	240	240	260
Total Superheat Surface	2,390	4,000	4,000	4,320
Working pressure	180	220	220	220
External diam. of boiler tube—				
Plain	2½in.	2¾in.	2¾in.	3in.
Stay	2½in.	2¾in.	2¾in.	3in.
Internal diam. of superheater tubes	13 mm.	13 mm.	13 mm.	15 mm.
Forced draught	Howden	Howden	Howden	Howden

In the case of the "Port Augusta" no alteration was made to the boilers, the grate surface, or any of the saturated steam connections, the only change or addition being in the case of pipes or connections coming in contact with the superheated steam, and some modification was made to the smoke boxes to allow of the superheater headers being fitted. The alterations to the engines consisted, in addition to the usual general overhaul, of fitting a balanced flat valve in place of the ordinary "D" valve for the M.P. engine, fitting of suitable piston rod metallic packing, steel neck bushes instead of brass, and additional lagging to cylinders, &c. A gravitation filter was installed and afterwards enlarged and improved until its efficiency was satisfactory.

The "Port Lincoln" and "Port Macquarie" are duplicate vessels in every respect; they have no auxiliary boiler, so that all demands for steam are supplied by the main boilers; these are increased above the usual requirements of auxiliaries owing to the vessels being fitted up for emigrants, which necessitates additional galleys, pantries, refrigerator machine, and electric light. The "Port Albany" is a duplicate of the "Port Lincoln," but fitted for carrying frozen cargo, and not fitted for emigrants.

Before dealing with the tabulated results of the performances of the steamers under consideration, some description of the data available and the basis on which the deductions have been drawn is essential for the purpose of arriving at their value. Mercantile steamers are for the commercial purpose of carrying passengers and cargo at remunerative freights, and, to do so, the cost of running involves a heavy expenditure for fuel, either coal or oil, the ordinary means of ascertaining such expenditure on the fuel account is by calculating the tons of fuel used per day. The results in Table III. are not compiled upon data, such as are available in a laboratory, on the "test" table, or even on a "trial trip" with a special staff of engineers to collect the same over a few hours, or perhaps days, but they are the averages of months and years of every day's work, which for commercial purposes is the best guide, as representing what the shipowner has to pay for.

Table III.

Average of Consecutive Voyages.	S.S. "Port Augusta." Triple Expansion. With Saturated Steam.	S.S. "Port Augusta." Triple Expansion. With Superheated Steam.	S.S. "Port Lincoln" and "Macquarie." Quadruple Expansion. With Superheated Steam.
"Port Augusta," London to Adelaide, via the Cape	7	5	—
"Port Lincoln" and "Port Macquarie," London to Melbourne, calling at the Cape	—	—	6
Days on voyage	46d. 10h. 46m.	49d. 12h. 2m.	41d. 1h. 35m.
Days under steam	45d. 17h. 38m.	46d. 14h. 1m.	39d. 2h. 43m.
Boiler pressure in pounds per square inch	180	180	220
Speed per hour in knots	10·67	10·46	12·7
Draught (mean) leaving London	24ft. 9½in.	24ft. 5½in.	24ft. 10¾in.
Displacement leaving London (tons)	10,150	10,000	12,266
Coals used for all purposes	1,744	1,560·45	2,335·05
Less deductions for raising steam, banked fires, winches, galley fires, crew's bogies and condensing fresh water	34	15·0	61·88
Coals used for main boilers for supplying steam on voyage for main engines and auxiliaries, also steering gear and electric light	1,710	1,545·45	2,273·17
Less deduction for "Port Augusta" steering gear and electric light at 1 ton per day	46	49·5	—
Less deduction for "Port Lincoln" and "Port Macquarie," including also steam cooking process and boilers and provision refrigerator machine at 2 tons per day	—	—	81·9
Coals used for main engines and auxiliaries (circulating pump, feed pump, evaporator, and fan)	1,664	1,495·95	2,191·27
Do. per day (tons)	36·65	32·1	56·0
Do. per indicated horse-power in pounds per hour	1·6	1·4	1·29
Quality of coal as indicated by loss reported voyage (ashes, &c.)	14 per cent.	13 per cent.	16·4 per cent.
Indicated horse-power	2,102	2,005·4	4,027

The data available with the triple-expansion engines of the "Port Augusta" comprise seven consecutive voyages extending over three and a half years using saturated steam, as well as the five following voyages after being fitted with superheat, extending over three years, all of which are from London to Adelaide via the Cape of Good Hope, most of them being without any call at an intermediate port. The reason that the outward voyages have been taken is, not only that they cover the same run, but also because the same bunkers for the whole voyage were taken either on the Tyne or at Middlesbrough from the Auckland (Durham) or Mickley coal seams. The conditions, therefore, are exceptional, if not unique, for the purpose of comparison.

The data dealt with of the quadruple expansion engines of the s.s "Port Lincoln" and "Port Macquarie" are on exactly the same basis as that of the "Port Augusta," and cover three voyages of each steamer to Melbourne from London calling at the Cape, with this difference, that two-thirds of the bunkers for the voyage were Mickley coal (unscreened) and one-third Natal coal, which latter gives a higher percentage of loss (ashes, &c.) and consequent consumption, than the North Country coal. There is also a deduction of two tons instead of one ton a day, on account of these steamers carrying more than 600 emigrants, besides a crew of 125, or about 740 souls all told, entailing a heavy expenditure of coal for galley fires, bakers' ovens, and steam for the cooking presses, boilers, pantry sinks, plate heaters, &c.

The results in Table III. cover all the contingencies which arise on a long sea voyage—weather, adverse trade winds, currents, also coal troubles arising from its being only "fair," or what is described as "dirty" or "small"; further, the human element is included, a most important factor affecting voyage results. Therefore these data have a special value to the shipowner.

The engineer naturally asks for a higher standard, by which to gauge the capabilities and possibilities of the use of superheat. For this reason, the results of a selected voyage, from London to Capetown, of one of the steamers fitted with quadruple engines is given when the coal was described as "good" but "small," the weather was "fair to good," and the stokehold crowd well up to the average. Then we get:—

	Selected.	Average of Five Voyages.
Days on passage	19 days 10 hours	19 days 17 hrs. 28 mins.
Speed	12·92 knots	12·77 knots
Coal consumption per day for main engines and auxiliaries	50·33 tons	51 tons
Coal per indicated horse-power	1·043	1·15
Indicated horse-power ..	4,500	4,122

The part of the voyage from the Cape to Australia is generally more detrimental to exhibition results owing to weather conditions, as well as to the less satisfactory quality of Natal bunker coal taken at the Cape, which consequently increases the daily consumption without any increase of indicated horse-power. From the results obtained we get the following consumption:—

	Lbs. per I.H.P. per hour.
Triple Expansion, Saturated	1·6
Triple Expansion, Superheated	1·4
Quadruple Expansion, Saturated	1·34
Quadruple Expansion, Superheated	1·15

The figures for quadruple engines with saturated steam are taken from similar data of two steamers fitted with engines of 3,000 i.h.p. during seven voyages each to Australia, via the Cape, with the same bunkers as used for the superheated quadruple engines as far as the Cape already dealt with.

In the following comparison of the economy obtained the consumption for quadruple engines superheated is taken at 1·15lbs. per hour per indicated horse-power obtained on the voyage as far as the Cape, because coal from the same collieries, viz., Auckland or Mickley, was burnt as was used on the other steamers. In the case of the voyage averages of the "Port Lincoln" and "Port Macquarie," the consumption works out at 1·29lbs. per hour per indicated horse-power in consequence of one-third of the coal being from Natal, giving a higher percentage of loss.

These results are shown on the accompanying diagram up to 10,000 i.h.p.

The additional cost of fitting superheat cannot be set down at any definite figure, as, although a large number of installations have been fitted, the different conditions that have to be complied with make a comparison, in order to form a standard of price, very conflicting; still, for rough estimating, it may be taken as ranging from 15s. to 20s. per indicated horse-power, against which the reduced size and consequent cost of the boilers must be considered.

The full benefit of superheat can only be obtained by extending its use to all the auxiliaries, and this has been carried out on the vessels fitted when new. The steam pipes are of steel and gland packings mostly metallic. The temperature used is about 500 Fah. and is regulated by a mixing

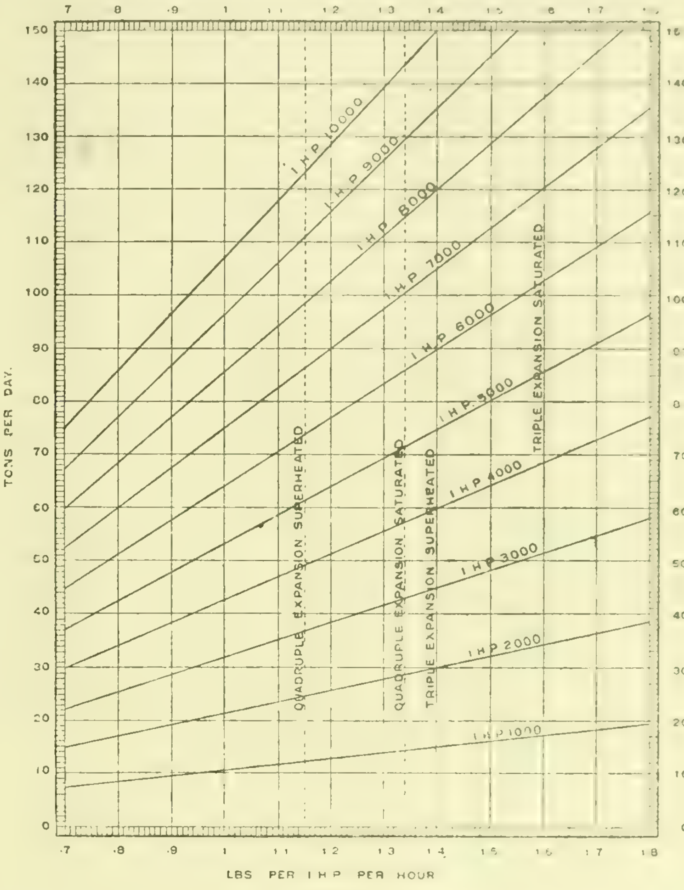


FIG. 1.

valve from the saturated steam pipe line. This arrangement ensures dry steam to the auxiliaries without any injury, although they are not all specially constructed for the use of superheated steam. Most of the leading makers of auxiliary engines make the necessary alteration for moderate superheat with but little if any extra charge. The mixing of superheated steam with the saturated supply for the winches is also a great advantage, even though very little superheat, if any, gets so far. The use of superheat on turbines is another and most interesting phase of the subject, and one on which a résumé of experience would be most valuable whether on the turbine direct or after passing through the reciprocating engine.

The data on the use of superheated steam during the last three years contained in this paper have been collected by the writer's firm in their professional capacity of consulting

Economy and Saving of Coal in Tons per day per 1,000 Indicated Horse-power.

	Lbs. per I.H.P. per hour.		Lbs. per I.H.P. per hour	Economy per cent.	Saving Tons per day per 1,000 I.H.P.
Triple expansion superheated at	1·4	over triple expansion saturated at......	1·6	12·14	2·14
Quadruple expansion saturated at	1·34	.. ..	1·6	16·25	2·79
,, ,, superheated at	1·15	.. ..	1·6	28·1	4·82
.. ..	1·15	,, ,, ,, superheated at ..	1·4	17·85	2·68
.. ..	1·15	.. quadruple .. saturated at......	1·34	14·2	2·03

engineers to the owners of the steamers. The fact that superheat has been fitted in all their subsequent vessels built, after a careful comparison as judged from the owner's standard of coals paid for, prompted the writer to place this information before the members of the Institution as pointing to the facts: (1) The economy of coal claimed is maintained. (2) The economy with triple-expansion engines of 2,000 i.h.p. after being altered to use superheat has been 12·14 per cent. (3) The economy with quadruple-expansion engines fitted with superheat over triple-expansion similarly fitted is about 17·85 per cent. (4) The wear on the machinery is not appreciably increased where proper lubrication of internal surfaces is maintained. (5) The filtration of oil from the feed water has been succesfully carried out so as to ensure the satisfactory condition of the same. (6) No danger from oil getting into the boiler need be feared with a filter such as was used. (7) The arrangement and fitting of the superheater elements and pipe connections present no serious objections. (8) The maintenance of the superheater elements in an efficient condition requires only ordinary attention. (9) In using superheat there is no necessity to carry any additional spare gear. (10) There is no necessity to carry any spare superheater elements. (11) The first cost has been recovered in one year on the basis that the vessel is under steam for 200 days, as a result, not only of the saving of bunker coal, but also of the additional freight carried in lieu of the weight saved thereby. In subsequent years the whole gain is for the profit of the shipowner subject to, say, 5 per cent. of same for additional overhaul and maintenance of the superheater elements, &c., and the usual allowances for insurance and depreciation on first cost. (12) All that is required to obtain these benefits is to instil confidence into the engineers in charge, and to see that the working instructions are implicitly carried out.

The number of steamers fitted with superheaters during recent years is an indication of successful working under superheat conditions. The following figures, though far from being a complete record, are worthy of note and consideration:—

	No. of Steamers.	Total I.H.P.
Hide Superheaters	20 ...	-
Yarrow ,, ...	13 ...	261,000
Babcock and Wilcox Superheaters ...	29 ...	316,675
Thornycroft Superheaters	— ...	60,000
Schmidt's	1,042 ...	1,322,092

STEEL IN CUPOLA MIXTURES.

According to H. M. Ramp, in an article on "Condensed Steel Mixture in Machine-tool Castings," in the "American Machinist," the admixture of steel improves the strength, fineness, and uniformity of grain and corrects the internal shrinkage of cast iron. The tensile strength is, he states, increased more than transverse strength. According to an accepted formula multiplying transverse strength of cast iron by 8·2 will give its tensile strength, but the average of several hundred tests made by Mr. Ramp on cast iron containing 25 to 50 per cent. steel scrap in the mixture shows that this factor would then have to be 10·4. With the mixtures containing 5 to 10 per cent. steel, the multiplier 8·2 will remain unchanged. Iron containing 40 per cent. steel scrap broke at 45,000lbs. per square inch with the inch square transverse bar breaking at 4,050lbs. The use of steel increases wearing efficiency and in quantities of from 5 to 10 per cent. tends to correct the evils of internal shrinkage. Some of the disadvantages in the use of steel scrap in cast iron are: (1) If the silicon runs low it will set up high shrinkage in the gates and risers and in the castings themselves. (2) If the phosphorus is low the iron will lose its life more quickly than iron of the same composition without steel and will not run so well. (3) It develops a greater degree of hardness in the presence of sulphur and appears to absorb more sulphur during the melting process, due however to possibly the use of more fuel necessary to melt and reduce it. (4) It increases the contraction of cast iron from the pattern size. Steel of as light a section and as uniform in composition as possible should be used. Ten per cent. more fuel is necessary than in an ordinary heat and the steel should always be charged first. The iron must not be used until a full charge is collected in one ladle, to avoid the variation which takes place if tapped in small quantities.

A NEW DRY GAS CLEANING PROCESS.

Prof. E. Mayer, of Aachen, in a contribution to "Stahl und Eisen," gives particulars relating to the comparatively new dry method of cleaning blastfurnace gas operated under the W. F. L. Beth patents, and we are indebted to "The Iron Age" for the following translation.

The plant at which the tests were made is the Halberger Hütte in Brebach, the arrangement being shown in the illustrations. In general it consists of a pre-cooler, a pre-heater, the filter boxes, and the fan. It is built for a normal capacity of 10,600ft. per minute measured at 0° C. and 760 mm. pressure. Photographs of plants are given in the original paper, one at the Röchling Eisen und Stahlwerke, Völklingen, giving 74,200 cub. ft. of cleaned gas per minute, and another at the Burbacher Hütte under construction, which is to give 141,340 cub. ft. per minute.

The raw dirty gas comes to the plant at greatly varying temperatures. Sometimes it is at only 50° C. and is then saturated with moisture; at other times it occasionally rises to 200° C. It first passes through the pre-cooler, being cooled a certain specified amount to 60° to 70° C., and then it goes to the pre-heater. In this way the gas is put in condition so that it does not injure the fibres of the filtering bags by being too hot, and, on the other hand, it is so far overheated that during the cleaning process it remains above the dew point. In this way disturbance of the process by water being deposited in the pores of the filtering bags is prevented with certainty. Waste gases from the stoves are used in the pre-heaters, being drawn through pipes by a fan. In exceptional cases where the waste gases exceed 200° C. in temperature and the pre-cooler cannot sufficiently cool the gases, the pre-heater can be used for cooling by drawing air through the pipes instead of hot waste gases. This can be done automatically by means of an electric thermostat. If this is not sufficient then water can be sprayed automatically into the gas in the pre-cooler until the desired temperature is reached. The water carried over by the gas must then be again vaporised in the pre-heater.

The chief cleaning is done by filtering in the so-called filter boxes. They are made up of several divisions, in each of which hang vertically a number of the filter bags, open at the lower end. They are made of a specially prepared cloth. The gas passes through these bags from the inside and from below, the dust remaining on the inside. Some falls of itself into two hoppers at the bottom of the filter boxes and is removed by electrically-operated screws to dust boxes, from which it is taken at intervals as found necessary. The greater part of the dust must, however, be removed from the bags by a special process. For this purpose the current of gas is reversed for a short time, in any particular division of the filter boxes, by means of a reversing valve. Clean gas taken from behind the fan, and therefore at high pressure, passes through the bags from the outside to the lower part of the filter boxes. At the same time the bags are shaken by suitable mechanism and thorough cleaning is the result. This gas used for cleaning is heated by a Beth patented process, so as to avoid clogging up and dirtying the bags with separated moisture. In the illustrations two divisions are shown at the left, one in normal operation, while the other is represented as being cleaned. The results of the test are given in the table. This test was carried out under the personal supervision of Prof. Mayer for the Blastfurnace Committee of the Verein deutscher Eisenhüttenleute. It extended over several days, the greatest care being taken to get accurate results.

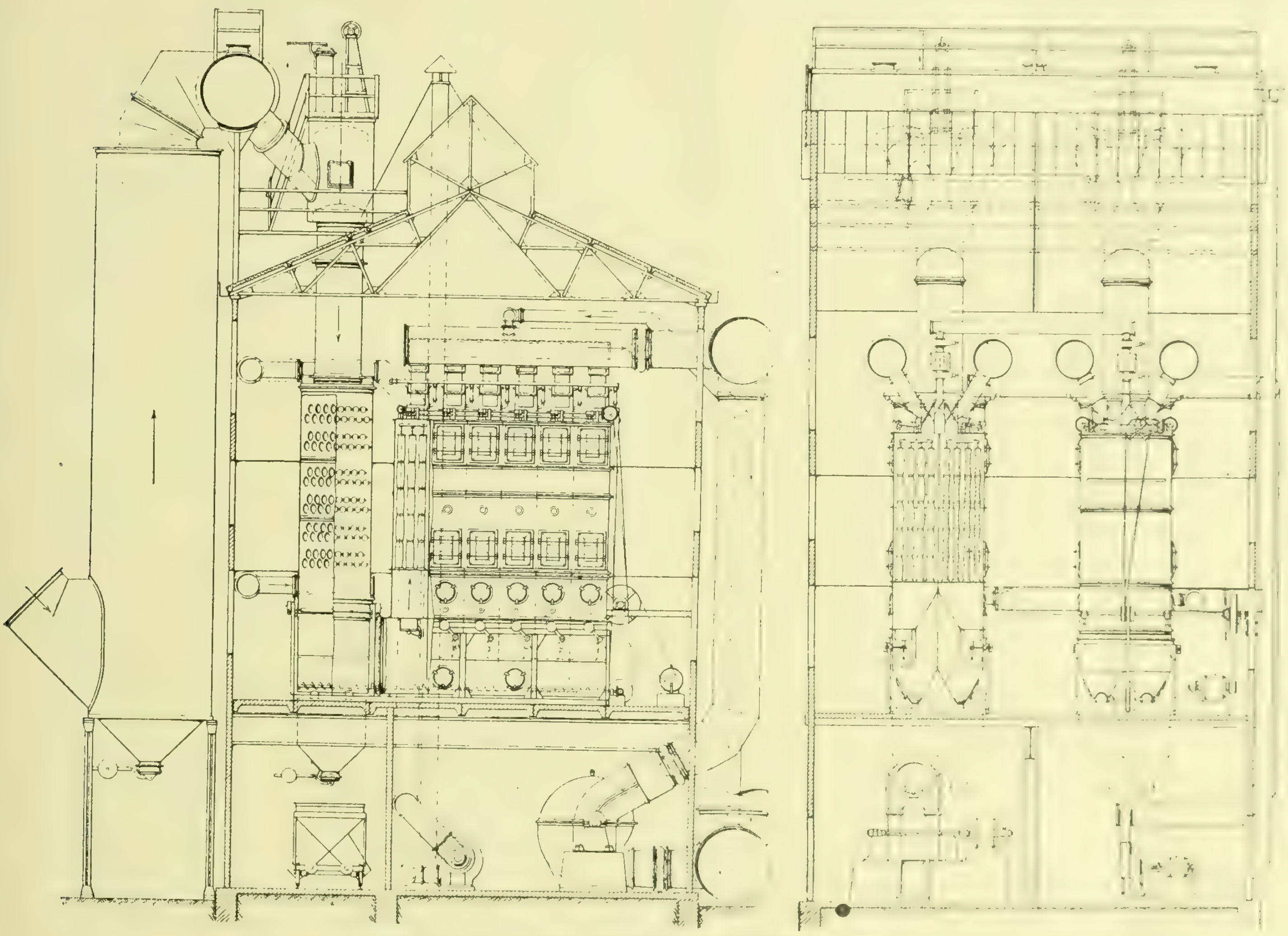
The test was made in April, 1912, the filter bags having already been in service for eight months. Between the fan and the gas engines there are two cooling towers. Behind the fan the dust contents of the gas were 0·0052 gr. per cubic foot. The results show that the plant was being burdened 30 per cent. over its normal capacity. The dew point of the gas containing 56·37 grs. moisture per cubic foot is about 54° C.; it leaves the fan at 69° C., which is 15° C. excess temperature.

The remainder of the paper is taken up with a discussion of the effect of the moisture contents, which is high compared

with that of gas cleaned and cooled by wet processes. The feeling is often expressed that such gas is not so suitable for combustion in the stoves. He believes that the heat required

Results of the Test.

Amount of cleaned gas furnished per minute:	
At 62° C. and 758 mm.	16,833 cu. ft.
At 0° C. and 760 mm.	13,713 cu. ft.
Dust contained in raw gas (0° C. and 760 mm.) per cu. ft.	1·82 gr.
Dust in cleaned gas, just in front of gas engines (0° C., 760 mm.)	0·00019 gr.
Static pressure in the raw gas main	1·32 oz.
Static pressure in the clean gas main	4·44 oz.
Temperature, raw gas main	67·8° C.
Temperature, clean gas main	62·0° C.
Moisture contained in clean gas (22° C. and 748 mm.) per cu. ft.	56·37 gr.
Total power, measured at the three motor shafts	66·8 h.p.
Power used by fan to give 3·12 extra oz. pressure	22·4 h.p.
Power for the cleaning process alone	44·4 h.p.
Power required per 1,000 cu. ft. clean gas (at 0° C. and 760 mm. pressure) without increase of pressure	3·24 h.p.
Power required for 1,000 cu. ft. clean gas, per 2·275 oz. increased pressure (100 mm. H_2O)	1·19 h.p.



SECTIONAL VIEWS OF DRY HALBERG-BETH GAS CLEANING PLANT

to dissociate the moisture is completely recovered, for with any decrease in flame temperature the water forms again, giving off the same heat previously taken for its dissociation. He also believes that higher flame temperatures will be reached because of the far better mixing of gas and air that can be obtained in the burners, due to using cleaned gas free from dust.

Association of Railway Signal Engineers.—The 48th conference of the Association of Railway Companies' Signal Superintendents and Signal Engineers (England) will be held at the Railway Clearing House, London, on Thursday, May 7th. 1914.

INFLUENCE OF ALUMINIUM UPON STEEL IN INGOTS AND RAILS.

AT the annual meeting of the American Railway Engineering Association a report of the committee on rails was presented in which Mr. M. H. Wickhorst gave the results of an investigation made to ascertain the influence of aluminium on Bessemer ingots and rails, when added to the moulds while pouring the steel. Some tests were also made to ascertain the influence of silicon on Bessemer rails when added as ferro silicon to the moulds. Four ingots were split open and a chemical survey was made of these; 11 were rolled into 85lb. or 90lb. rails and used for drop tests and transverse tests of the base. This work was done at the South Chicago works of the Illinois Steel Company, which furnished all the material. Five ingots were of untreated Bessemer steel, eight were treated with aluminium varying from 1oz. to 10oz. per ton of steel, and two ingots were treated with additions of ferro-silicon equivalent to 0·1 and 0·2 per cent. of silicon respectively. These latter were rolled into rails.

The ingots used for splitting and chemical survey had about 0·44 per cent. carbon. The plain ingot had a large central cavity or pipe in the upper part and a large number of small elongated holes along the sides in the upper part. This ingot also had a raised top. The other three ingots treated respectively with 1oz., 2oz., and 5oz. of aluminium per ton of steel, had somewhat larger pipes, but were free from the small elongated holes along the sides. They had flat or sunken tops. Expressed differently, the aluminium-treated ingots had larger pipes, but contained denser steel around the pipes. One ounce of aluminium per ton had considerable influence in this direction and the effect increased a little with increase of aluminium. The chemical surveys showed a more even distribution of the material in the aluminium-treated ingots, with less segregation or concentration of carbon, phosphorus, and sulphur in the interior and upper part. Both plain and treated ingots showed "soft centres" in the

lower part of the ingot, *i.e.*, there was negative segregation of carbon, phosphorus, and sulphur in the interior and lower part of the ingot. The walls of the treated ingots showed a fairly uniform composition throughout their heights. The plain ingot showed a considerable softening or negative segregation in the upper corners. The carbon, phosphorus, and sulphur increased in the wall downward until the average composition of the steel was reached at about one-third of the height from the top, after which the wall remained of about uniform composition.

Rails were made of steel of two grades of hardness, one of about 0·45 per cent. carbon rolled into 85lb. rails and the other of about 0·61 per cent. carbon rolled into 90lb. rails. Some were of plain steel, some treated with aluminium varying from 2oz. to 10oz. per ton and two were treated with 0·1 and 0·2 per cent. of silicon added as ferro-silicon. In the drop tests, the use of aluminium was in general attended with a considerable increase in ductility in the upper part of the bar, where the ductility was low in the plain steel, especially with the higher carbon. The addition of silicon had a similar effect especially with the 0·2 per cent. addition. With the 0·45 per cent. carbon steel, the average ductility of the whole bar was about the same in the aluminium treated as in the plain steel, but with the 0·61 per cent. carbon steel, it was considerably greater in the aluminium-treated bars. The aluminium additions and the larger additions of silicon were attended with interior flaws extending downward a considerable distance (30 to 45 per cent. of the weight of the ingot) from the top, while with plain steel interior laminations as seen in the fractures of the drop-test pieces were absent or close to the top end. The aluminium and silicon additions were made to the moulds while pouring the steel, and whether the interior laminations in the rails would occur in the same way if the additions were made to the ladle before pouring the steel into the moulds, this investigation does not show.

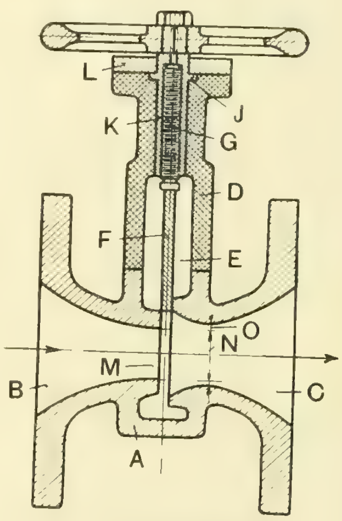
Incidental to this work, some results were obtained concerning the influence of carbon on ductility as measured in the drop test. The elongation for 0·45 per cent. carbon averaged about 27 per cent. and for 0·61 per cent. carbon about 17 per cent. Roughly, the elongation decreased 0·6 per cent. for each 0·01 per cent. increase in carbon, between the above carbon limits. Transverse tests of the base were made by supporting pieces of rail 2ft. long, on two supports placed opposite each other near the edges of the flanges under the middle of the length of the piece tested. The supports were 6in. long and were placed ½in. in from the sides of the flanges. The load was applied in the test machine to the head of the rail at the middle. With the 0·61 per cent. carbon steel, treatment with 2oz. of aluminium was attended with considerable increase in transverse strength and sag of flange before breaking. With treatments with 5oz. and 10oz. of aluminium per ton of steel, there were some further increases. With the 0·45 per cent. carbon steel, there were small increases in transverse strength and sag of flange with the aluminium treatments as against plain steel.

To sum up, ingots treated with aluminium added to the mould were of more even composition throughout than plain Bessemer steel. There was less positive segregation in the interior and upper part of the ingot, but the negative segregation or soft centre in the interior and lower parts of the ingot was about the same. There was a softening or negative segregation in the upper part of the wall of the plain ingot, while in the aluminium-treated ingots the walls were of fairly even composition throughout the height of the ingot. Aluminium-treated ingots had larger and deeper pipes than plain steel, but had denser steel around the pipes.

Rails of plain steel had a brittle zone in the upper part of the bar as disclosed by the drop test. In the rails of aluminium-treated steel this zone was largely eliminated. Rails of plain steel contained their laminations close to the top end of the bar, while in aluminium-treated rails, the interior laminations were found a considerable distance from the top end, varying from about 30 to 45 per cent. of the weight of the ingot. In the transverse test of the base, rails of aluminium-treated steel showed a considerably greater transverse strength of the base and sag of the flange before breaking than the rails of plain steel, with 0·61 per cent. carbon, and a little greater strength and sag of flange with 0·45 per cent. carbon.

STOP VALVE FOR SUPERHEATED STEAM.

Stop valves are well known in which the inlet and outlet taper like a nozzle towards the closure member proper, the narrowest cross-sections of the two nozzles being, however, equally large. The object of this arrangement is that the pressure medium may flow on the Venturi principle without material fall of pressure. In a valve formed in this manner, however, even when the cross-section of the outlet nozzle is enlarged only a little directly at the gate, no pressure below atmospheric can be produced round the valve chamber, because there can be no injector-like action of the two nozzles when the narrowest cross-section of passage is equal. The design of stop valve illustrated, the invention of Mr. Hugo Lentz, of 18, Bornimerstrasse, Halensee, near Berlin, is based on using a certain, even if exceedingly small, part of the energy of flow of the pressure medium for producing a pressure below atmospheric about the closure member; this low pressure allows the latter to be packed with very simple means and enables the valve box to be formed in a simple manner, whatever size the stop valve may be. This pressure below atmospheric is obtained by making the narrowest cross-section of the outlet or discharge nozzle larger than the narrowest cross-section of the inlet or admission nozzle; the magnitude of the difference between the two will depend, according to the size of the valve, on the pressure below atmospheric which is produced, as in an injector, being sufficient for enabling the valve disc or gate and the spindle which actuates the latter to be simply and readily packed, and the spindle to be readily lubricated. In such a form the valve disc or gate can be actuated very readily because the full pressure does not act on the spindle. As a fall of temperature is connected with the pressure below atmospheric that part of the valve box which contains the valve disc or gate will have a lower temperature than the pressure medium which flows through it, so that the heat radiated by the valve box is materially diminished. The connection of a small and a large nozzle in series also has the material advantage that the pressure medium passes smoothly over the joint and the formation of eddies is avoided.



Stop Valve for Superheated Steam.

Referring to the illustration, the valve box A has an inlet or admission nozzle B and an outlet or delivery nozzle C which can be separated by the gate F. Both nozzles taper towards the gate F, but the narrowest cross-section M of the inlet nozzle B at the end thereof is smaller than the narrowest cross-section N of the outlet nozzle C, the difference between the two sections being designated O. Surrounding the adjacent ends of the two nozzles separated from one another by a distance equal to the breadth of the gate is a chamber or space E which receives the gate F. This gate is connected above to a threaded spindle G which engages with a corresponding sleeve K, which in turn is rotatably mounted in the bonnet D, but is prevented from axial displacement by a collar J and the cover L. A hand wheel is attached to the nut K. When the hand wheel is turned the spindle G of the gate F shifts inside the nut H, whereby the gate can be opened or closed. When the valve is open, in consequence of the shape of the nozzles and of the larger cross-section of passage of the outlet nozzle at the gate, a pressure below atmospheric is produced as in an injector in the chamber or space E which has to be packed, whereby the above-mentioned advantages are obtained. By suitably selecting the annular cross-section O it is possible to pack valves of all sizes in a simple manner.

PRESENT POSITION OF DIESEL ENGINES FOR MARINE PURPOSES.*

BY J. T. MILTON.

THERE are several types of Diesel engine at present working at sea, and some others are in course of construction. It is proposed first to mention the principal features of each type, then to give as far as possible a statement of the experience with the vessels fitted with each of the types, and finally to offer some remarks upon the different points which these experiences have shown to require consideration.

Diesel engines are broadly divided into two classes, viz., the 2-stroke and the 4-stroke cycle respectively. In both types a cylinder full of air at atmospheric pressure is compressed by the piston till at the top centre its pressure becomes about 500lbs. per square inch. The compression raises its temperature to about 1,000° Fah. At this instant a small quantity of oil fuel is blown into the very hot high-pressure air by means of a blast of air at still higher pressure. The arrangement of the fuel valve and its gear is such that the oil is broken into a fine spray, and its admission lasts only for the short time which it takes for the piston to perform about one-tenth of its downward stroke. During this short time much of the oil becomes burned in the hot air. The heat generated by the combustion raises the temperature considerably, and consequently must increase either or both the pressure and the volume occupied. What is aimed at is that the combustion should proceed at the critical rate which would permit the increase of volume occupied due to the motion of the piston and the increase of temperature to be so balanced that the pressure will remain constant until the whole of the oil has been burned. After this the expansion of the hot gas will still further push the piston down, and the pressure will rapidly decrease. The temperature will also rapidly fall, mainly through the conversion of some of the heat into work, but partly also by some of it being conveyed into the cylinder surfaces, these being kept comparatively cool by water circulation. The maximum temperatures actually attained in the cylinders are very high, approximating in some cases to nearly 3,000° Fah. It is these excessively high temperatures which occasion some of the special difficulties of Diesel engines. It is necessary to keep the rubbing surfaces of the metal, which is exposed to the hot gases, sufficiently cool to permit of their retaining their lubrication, and it is also necessary to prevent all the metal with which the heat comes into contact from becoming so overheated as to damage its strain-resisting properties.

The foregoing remarks apply to all types of Diesel engines. In the case of the 2-stroke cycle engine, just before the completion of the expansion stroke the piston uncovers some ports in the lower part of the cylinder walls leading into an exhaust passage, and a considerable portion of the hot gas escapes, the pressure falling to about that of the atmosphere; then in some designs some valves in the cylinder cover are opened, and fresh air supplied by the scavenge pump at a pressure of about 4lbs. per square inch blows out the remainder of the burnt gas, leaving the cylinder full of fresh air ready to be compressed by the return stroke of the piston. In some designs the exhaust ports are placed on one side only of the lower end of the cylinder, and on the other side similar ports, also opened by the travel of the piston but at a somewhat later instant, admit the scavenge air. In these cases the tops of the pistons are curved to direct the entering air upwards, and it is claimed that the scavenge air travels right to the top of the cylinder and entirely displaces the burnt air. In these latter designs the scavenge valves and the gear for working them are dispensed with, and consequently the engines are to some extent simplified.

In the "Junkers" engine, which is another type of the 2-cycle engine and which will be referred to later, there are two pistons working in one cylinder. The exhaust ports are disposed round one end of the cylinder and are controlled by one piston in the manner first described, while the scavenge ports are placed at the other end and are similarly controlled by the other piston. The scavenge air in this case sweeps straight through the cylinder, as it does in the type of engine with scavenge valves situated in cylinder cover.

In the 4-stroke cycle engine the exhaust takes place through valves in the cylinder covers, the gases being pushed out by the piston on its return stroke. During the next stroke fresh air is drawn into the cylinder through other valves also situated in the cylinder cover. It is compressed during the third stroke, and the fuel is then admitted in the same manner at the commencement of the next stroke as in the 2-stroke cycle type.

It will be observed that in the 2-stroke cycle there is one impulse in each cylinder every revolution, while in the 4-stroke cycle there is only one impulse per two revolutions, so that with the same diameter of cylinder and the same piston speed double the number of cylinders have to be used with a 4-stroke compared with a 2-stroke engine of the same power, if the same mean pressures are maintained.

In both types a considerable part of the energy exerted during the impulse stroke is used up in the following compression stroke. Also in the 2-stroke cycle large scavenge air pumps have to be provided having an aggregate capacity greater than that of the whole of the cylinders, and considerable power is expended in working these pumps, and this must be taken off the effective power of the engine.

On the other hand the 4-stroke cycle engine has the engine friction (pistons, guides, shafts, &c.) during twice the number of strokes as compared with the 2-stroke cycle, and it also has to be provided with exhaust valves and gear to work them which are not required in 2-stroke cycle engines. On the whole there is no doubt that while the "indicated" power obtained from a stated quantity of oil is about the same in both types of engines working under similar conditions of compression and fuel supply, the 4-stroke cycle is somewhat more efficient than the other in that a larger proportion of the power exerted on the pistons is transmitted to the screw, owing to no scavenge air having to be supplied.

In land Diesel engines there are no piston rods, and consequently no piston rod guides. The pistons are made in the form of trunks. They are fitted with fixed gudgeons upon which the connecting rod top ends work, and the sides of the trunks rubbing on the cylinder walls form guides for taking the side thrust of the connecting rods. This form has not found favour with marine engineers, only one large vessel, viz., the "France," being fitted with this type of engine. In her case the engines were made by Messrs. Schneider, of Creusot, from designs by Messrs. Carels Frères. In all other large marine Diesel engines the pistons have been fitted with piston rods, the lower ends of which are arranged with guides. Specially forced lubrication has always to be arranged for providing a small but continuous supply of high-class mineral oil for lubricating each piston in its cylinder. In some cases the engines have all the other principal working parts lubricated by a circulation of oil under pressure, and in consequence these parts are all enclosed in a casing for containing the splash oil, which is collected, filtered, and cooled, and can then be used over and over again. Other engines are lubricated in the manner commonly employed in marine steam engines, and are made of the "open" type. Each style has its advantages and disadvantages as compared with the other.

All Diesel engines require to have compressed air for manœuvring and for blowing in the fuel. The air for both of these purposes has to be supplied by special compressors. Of these there are several types. In most cases, but not in all, the air for manœuvring is stored at a lower pressure than that which is required for fuel injection. This is generally considered to be the preferable method. It certainly is much safer, as the manœuvring valves must be arranged to permit the air pressure to be carried for a considerable part of the stroke, and it is not prudent to have to depend only upon wiredrawing the air to prevent an excessive amount of air pressure entering the cylinder and unduly straining the mechanism. Besides, a comparatively low and therefore safe air pressure is capable of doing all that is required.

In Messrs. Burmeister & Wain's engines of the "Selandia" type, the manœuvring air is taken from low-pressure reservoirs which are charged by 2-stage compressors worked by auxiliary Diesel engines. A high-pressure compressor worked by each main engine also takes it

* Paper read at the spring meetings of the fifty fifth session of the Institution of Naval Architects, April 2nd, 1914.

supply from the same reservoirs, and further compresses air into other receivers from which the injection air is taken. In the "Werkspoor" engines the main compressors are of the 3-stage tandem type worked by levers from the main engines. In the engines made by Messrs. F. Krupp and Co., at Kiel, the compressors are of the Reavell type, worked by auxiliary oil engines and not by the main engines. In the engines of the "France," which are of the Carels type, the compressor is a 3-stage tandem, worked direct from the main engine by a special crank and connecting rod. In the engines of the "Fordonian," "Eavestone," "Wotan," and "Rolandseck," all of which are also of the Carels design, the compressors are of the Reavell type, worked by the main engine. In the Nürnberg design of engine for cargo vessels, the compressor is tandem 3-stage, worked by levers from the main engine. In the "Monte Penedo," the engines were made by Messrs. Sulzer Bros., of Winterthur, and the compressors are also 3-stage tandem, worked by levers from the main engines.

In all cases auxiliary compressors have to be provided for in addition to the main compressors. These are necessary both as a stand-by in case of derangement of the main compressor, and also for supplying the extra air required for manœuvring the engines when entering docks, picking up moorings, &c. It will be seen that there is a great diversity both in the types of compressor and in the methods of working them. The consensus of opinion amongst marine engineers now is that in all cases of engines of small or medium power it is best to arrange the main compressors and also the scavenge pumps, where these are required, to be worked by the main engines; but in engines of large powers, in which the power required to work these accessories is considerable, it will become advisable to have them independent of the main engines, to enable the sizes of the cylinders of the main engines to be kept as small as possible. This is due to the recognised fact that the difficulties inherent in the Diesel engine become accentuated with increase of diameter of cylinder.

A special feature of the engines made at Stockholm and also those made by Messrs. Swan, Hunter, & Wigham Richardson, of Wallsend, and by Messrs. Benz & Co., of Mannheim, is that the mechanism of the scavenge pumps is used for manœuvring the engines. In most of these engines there are two pumps which in ordinary running supply the scavenge air. These are worked by a supplementary crank shaft in line with and connected to the main crank shaft. This supplementary shaft has two cranks at right angles. The scavenge pumps are double-acting, and the arrangement provides a fairly uniform supply of scavenge air. When the engines have to be manœuvred by compressed air no scavenge air is required and these scavenge pumps virtually become working cylinders for driving the shaft. They are supplied with compressed air from the receivers and work in a manner similar to that of a 2-cylinder double-acting steam engine. In the largest engines made at Stockholm, fitted in the "Sebastian," the arrangement is that there is one scavenge pump immediately below each working cylinder, its piston being connected to the working cylinder piston rod. As in the other design the scavenge pistons, acted upon by compressed air, are used for manœuvring.

The "Junkers" engine has been mentioned as being one of the types of 2-stroke cycle. This has been made in two forms, the simple and the "tandem." In the simple Junkers engine the cylinder is made open at both ends and has two pistons fitted in it. The crank shaft has three cranks for each cylinder. The first and third are in the same phase, the second, which is between the other two, being opposite to them. The bottom piston has a piston rod which is fitted with a guide, and its connecting rod connects it in the usual manner to the central crank pin. The upper piston has its rod passing out of the top of the cylinder and connected to a guided crosshead. Side rods connect the ends of this crosshead to side connecting rods, which work upon the two outer (1st and 3rd) crank pins, the top ends of these connecting rods being guided similar to the upper end of the centre connecting rod. The arrangement is such that the two pistons work in opposite directions in synchronism in such a way that they are both at the centre of the cylinder when the middle crank is at the top centre, and both at the ends of the cylinder when it is at the bottom centre. As has been mentioned, the scavenge air ports are at one end and the exhaust ports at the other end of the cylinder, both being fully uncovered by the two pistons at the instant when the pistons are at the ends of the stroke. The only valves required in each cylinder are the fuel valve and the air starting valve and a relief valve, all of which enter the cylinder at the middle of its length.

There are certain advantages claimed for this engine, the principal being that in proportion to the effective stroke (sum of the strokes of two pistons) the engine requires less height than any other type of Diesel engine. Also there are no cylinder covers required, parts which in some engines have given considerable trouble, and there being no covers the gas in the cylinder does not lose so much heat to the cooling water, and a higher heat efficiency is therefore obtained. The valve gear is reduced to a minimum. The bending strain on the crank shaft is very much less than in an ordinary Diesel engine of the same power, and consequently a smaller shaft can be used There are very small loads on the main bearings, and therefore there is a minimum of shaft friction. On the other hand there are three connecting rods and their accompanying rods and guides instead of one, although each one is much lighter, three crank pin brasses to lubricate, and there are also the guides of the side rods requiring attention.

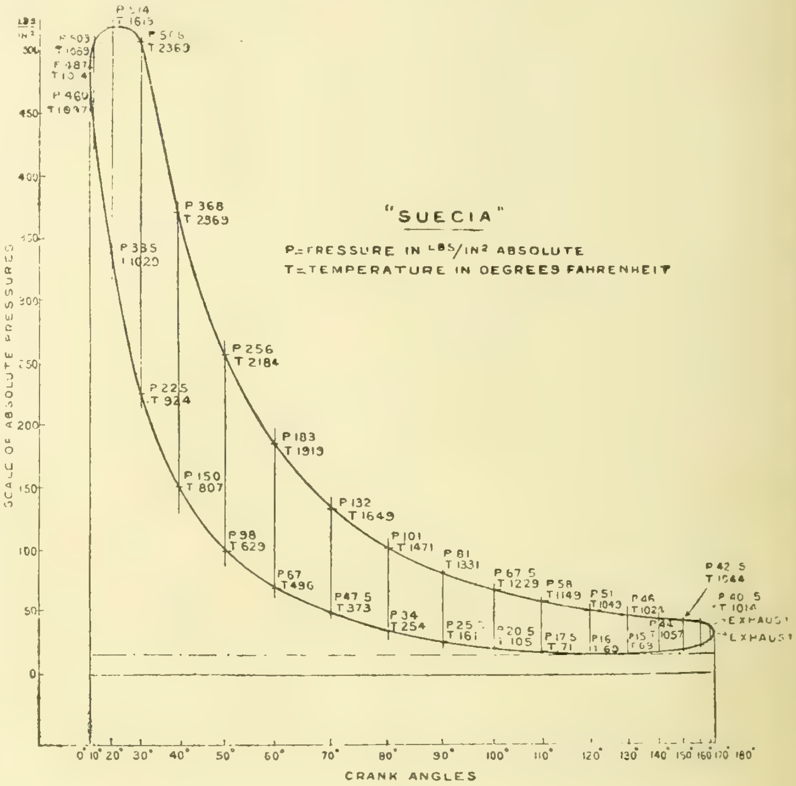


Fig. 1.

In the "Tandem" type a second cylinder is provided in line with, but above the lower one. This also is provided with two pistons. The lower is connected to the same crosshead as the upper piston of the lower cylinder, and works in unison with it. The upper piston is connected to a crosshead in a plane at right angles to that connected to the middle pistons, and this is connected by side rods to the guide of the lowest piston of the lower cylinder. The arrangement provides that the pistons of the upper cylinder are at the centre of their cylinder when those of the lower cylinder are at the ends of their stroke and vice versâ. By this means the pair of cylinders with their four pistons produce the effect of one double-acting cylinder, whereas, when only one cylinder is used, the action is that of a single-acting cylinder. As the impulse stroke of the upper cylinder occurs during the compression stroke of the lower and vice versâ, the effect of the two cylinders in tandem is to obtain double the power of the one cylinder without increasing the maximum strain on the crank and other shafts. The Junkers engine in its tandem form has been made by the Weser Company, of Bremerhaven, for a vessel owned by the Hamburg-Amerika Company. They have, however, not yet been tested at sea. The simple form of

engine has been fitted in the "Arthur von Gwynner," which commenced working at the beginning of January of this year.

Another form to be mentioned is the double-acting 2-stroke cycle engine. It is rumoured that large engines of this type have been, or are being, made for foreign warships, but so far none have yet been fitted to merchant vessels. The M.A.N. Company, of Nürnberg, in conjunction with Messrs. Blohm & Voss, made some 3-cylinder engines of this type for a merchant ship. The set made at Nürnberg was unfortunately destroyed by a fire which followed an accident at the works. At the present time Messrs. Blohm & Voss have in hand some engines of this type for a twin-screw vessel. These have been successfully run on the test bench, but not yet tried at sea. Their performance will be watched by marine engineers with much interest, as they occupy so much less space than any other type of Diesel engine. Being double acting they give the same number of impulses per cylinder per revolution as are obtained in a steam engine, and are thus in marked contrast with the 4-stroke cycle single-acting type.

From the point of view of a registration society, as well as of a shipowner, reliability under the conditions of ordinary service is of the first importance, questions of economy of running and of upkeep becoming relatively of secondary interest, although they are still very important to the shipowner. Dealing with economy of running in the first place, it may be mentioned that whereas in special trades a constant supply of one uniform quality of oil can be obtained, it is necessary for the success of the engines in general that they shall be able to use the particular quality of oil which may be obtainable at any of the ports to which the vessel trades. Dr. Diesel always maintained that any oil which would burn without leaving a residue could be used as fuel in these engines; and it may be of interest to know that Prof. Junkers has experimented with several kinds of oils, some of which were considered by some engineers to be unsuitable for use owing to the large percentage of asphalte, or unevaporable hydrocarbon they contain, and he has found them to burn perfectly satisfactorily when they are properly treated. Some of his results are as follows:—

In all the cases quoted the experiments were made on the same engine, which is a small experimental one, with cylinder diameter of 8in. and a piston stroke (each piston) of 16in. At 200 revolutions the normal load is 150 b.h.p., but arrangements are made by which an overload up to 220 b.h.p. can be obtained with the same number of revolutions. The overload is obtained by so obstructing the exhaust that the scavenge air imprisoned in the cylinder at the commencement of the stroke is above the atmospheric pressure, and at the same time more fuel oil is injected during the impulse stroke; in other words, more fuel and more oxygen to burn it are used at each stroke. Of course with the greater amount of air used a

TABLE I.

	Mexican Crude Oil.	German Coal Tar Oil.	Gas Oil.	Pacura (Roumania).	Mazut (Russian).	Californian Residue. Brand K	Brand L
Carbon	83·21%	90·12%	86·98%	-	85·67%	84·00%	84·78%
Hydrogen	11·32	7·09	12·15	- -	12·13	11·07	11·85
Sulphur	2·43	0·63	·71	—	·05	·87	·84
Oxygen and Nitrogen	2·90	1·66	·16	- -	·72	3·93	2·45
Incombustible	·14	·50	-	—	1·43	·13	·08
Specific gravity	·937 at 12° C.	1·065 at 15° C.	·85 at 15° C.	·90 to ·98	·9 at 12° C.	·864	·935
Viscosity	4·11 at 64° C.	1·66 at 20° C.	1·14 at 20° C.		19·96 at 20° C.	6·41 at 80° C.	2·22 at 80° C.
Asphaltum	45·6%					18·1%	12·9%
Calorific Value in B.T.U.'s per lb.	17,460	15,950	18,000		17,800	17,400	17,550
Flash point		98° C.	80° C.	140° C.	113° C.	Ignites dish 137° C.	in open at 85° C.
						Average Results of Californian Oil.	
Normal Load Revs.	200	200	200	204	200	200	
Brake Horse-power	115·2	144	160			151·8	
Ind. Mean Pressure	10·0 At.	10·0 At.	10·5 At.	11·0 At.	11·0 At.	10·6 At.	
Max. Pressure	44·0 At.	46·0 At.		40·0 At.	47·0 At.	47·0 At.	
Thermal Efficiency	44·3%	45·0%	48%	46%	46·5%	44·7%	
Overload Revs.	200	200				200	
Brake Horse-power	212	-				197	
Ind. Mean Pressure	13·9 At.	13·6 At.	—	—	—	13·2 At.	
Max. Pressure	71 At.	64 At.				73 At.	
Thermal Efficiency	42·8%		—	-	- -	44·1%	

higher compression pressure is reached, so that the stresses on the engine are also increased when working with an overload. Prof. Junkers points out that, the engine being an experimental one, and the first of its type to be made, the results obtained must not be considered to be the most favourable attainable with oil engines; but, as the trials with different oils were all made on the same engine, and under the same rigid supervision, the results with the various fuels can be considered to be reliable for comparison with one another. In all cases the trials were very prolonged.

Table I shows some of the results obtained. It will be seen that throughout the trials recorded the mean indicated pressure was very high, in no case being less than 10 atmospheres (142lbs. per square inch), which very considerably exceeds anything which has been obtained with large marine Diesel engines, and that this high mean pressure was obtained with a maximum pressure of 47 atmospheres against 35 atmospheres usual in marine work. It must be mentioned, however, that trials were made showing that with each kind of oil used the engine worked well with low loads as well as with these high loads. It is worthy of remark that with the very high mean pressures obtained during the overload trials,

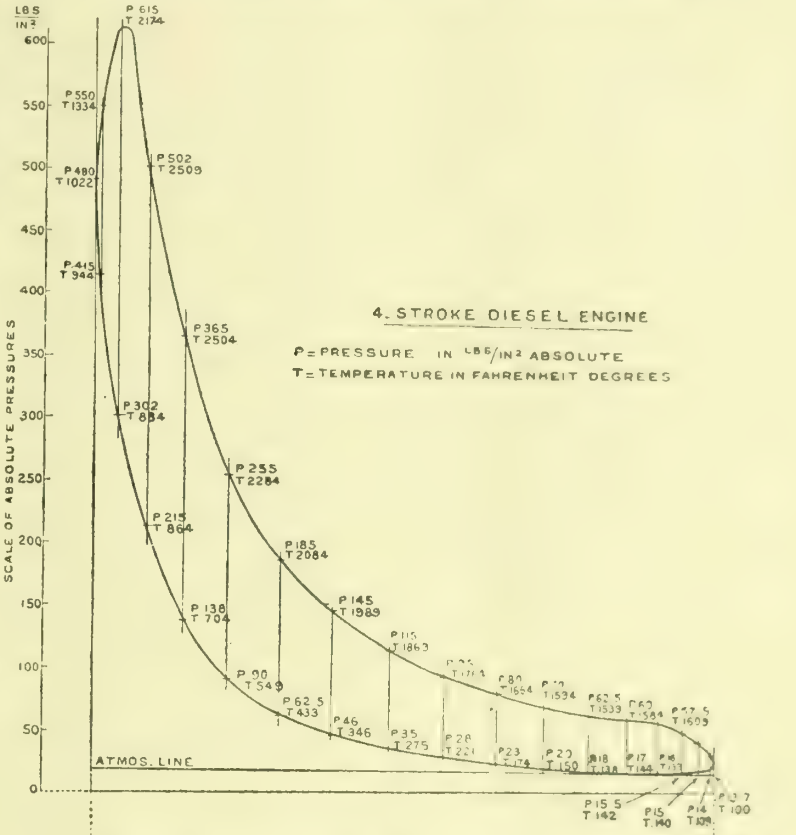


FIG. 2.

the terminal pressure was very high, in some cases being above 70lbs. per square inch, and consequently much energy must have been lost in the exhaust, yet the thermal efficiency was practically the same as at normal power. Incidentally attention may be drawn to the differences between the brands K and L of Californian oil, in which it will be seen that the oil with the higher specific gravity has less viscosity, less asphaltum in its composition, and ignites at a much lower temperature than the lighter oil.

It has been mentioned that what is aimed at in the Diesel engines is that the combustion should proceed at the critical rate which would permit the increase of volume occupied due to the motion of the piston to be so balanced by the increase of temperature due to the combustion of the fuel that the pressure will remain constant until the whole of the oil has been injected. This ideal condition is, of course, never obtained with any kind of oil, with any form of sprayer, or with any degree of compression. In general terms it may be said that the hotter the air into which oil is sprayed, other conditions remaining the same, the more quickly will combustion take place. Also the smaller the particles into which the oil can be divided by the sprayer the larger will be the aggregate surface exposed and the quicker will be the com-

bustion. Again, the less viscosity the oil has the more easily it becomes finely sprayed, and further, the greater the excess of pressure of the blast above that of the compression, the more quickly will the quantity of oil measured out per impulse into the fuel valve casing be blown into the cylinder, and probably also the finer will be the spraying. Then, again, some oils contain more of the lighter, highly inflammable hydrocarbons than others, and therefore they will more readily ignite and burn more quickly than the heavier oils, and again, some oils are capable of being completely vaporised, whilst others, generally spoken of as having an asphalte basis, consist partly of evaporisable components and partly of hydrocarbons which will not evaporise and are generally called asphaltes.

As has been mentioned, it has sometimes been considered that these latter oils cannot be used in Diesel engines, but Prof. Junkers' experiments show that this is a mistake. It will be thus seen that there are many conditions of detail in connection with the ignition which afford scope for skill and ingenuity. In no case can the combustion fully realise the ideal condition. The nearness or otherwise of the approach to it can be ascertained by a careful analysis of the indicator diagram. Such analyses always show that some combustion takes place along the whole of the stroke. When the combustion is far from perfect at the end of the stroke the exhaust will show smoke. A less imperfect combustion may leave carbonaceous deposits in the cylinder, which in time may so accumulate as to cause the piston rings to seize or become inoperative. Although there may be no smoke, part of the fuel may be burned only to CO instead of to CO_2, and, even if the combustion become actually complete before the end of the stroke, the ideal condition will not be obtained. What is wanted is that the heat should be produced early in the stroke, so as to give full opportunity for its conversion into mechanical energy. To show what may be done in this way one may compare the results obtained with an early 4-stroke cycle Diesel engine referred to in "Engineering" in 1903 as being a remarkably successful example, with that obtained more recently with the 4-stroke cycle engine fitted in the "Suecia." The diagram in the latter case was kindly supplied by Messrs. Burmeister & Wain, of Copenhagen, and is the mean of a large number of diagrams taken with these engines, and it will be seen that it agrees extremely closely with the typical diagram given by Mr. I. Knudsen in his recent paper to this Institution upon the performances of that vessel. This comparison is given in an Appendix to this paper.

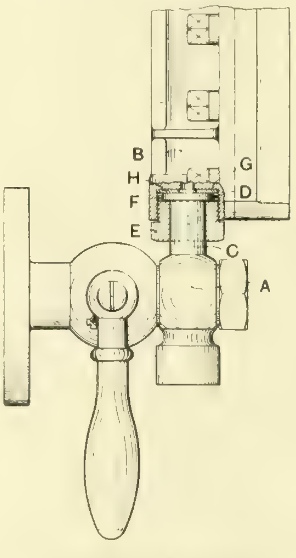
(*To be continued.*)

RESCUE WORK IN MINES: NEW DRAFT REGULATIONS.

Draft regulations amending the general regulations as to rescue appliances in mines, dated July 10th, 1913, made by the Secretary of State, under Sections 85 and 86 of the Coal Mines Act, 1911, were issued on the 16th inst. A memorandum accompanying the draft regulations states that in consequence of objections taken to previous draft regulations issued on November 7th last, the question was referred to a referee, and at the hearing an arrangement was suggested which appeared to the Secretary of State to be a good one, and which has now the assent of the representatives of both owners and miners. Under this arrangement the use of self-contained breathing apparatus will be made compulsory, but an alternative system for the establishment of rescue brigades will be admitted, by which, in place of the local brigades at the collieries now required, permanent brigades will be maintained at the central stations, and one or more men, according to the size of the colliery, will be trained at each mine to act with the central brigade when summoned to the mine. The terms of the new draft regulations have been settled with the Mining Association and with the Miners' Federation. If these regulations are accepted, the draft regulation issued last November will be withdrawn. Any objection with respect to the draft regulations by or on behalf of any person affected thereby must be sent to the Secretary of State within 30 days from April 16th. The draft regulations state that for mines served by a central rescue corps Nos. 140, 141, and 142 of the general regulations shall not apply to any mine which is served by a central rescue station maintaining permanent rescue corps, and which is situated within a radius of 10 miles from the station and is in telephonic communication with it, subject to the following (among other) conditions: The rescue corps at the central station shall consist of not less than six men, or if the total number of underground employés at all the mines served by the station in pursuance of this regulation exceeds 15,000, eight men. One or more persons employed at the mine for the time being shall be selected for the purpose of acting with the rescue corps from the central station when summoned as follows: If the total number of underground employés is not less than 100 or more than 250 persons, not fewer than one person; if the total number of underground employés is more than 250, but not more than 1,000, not fewer than three persons; if the total number of underground employés is more than 1,000, not fewer than five persons; they shall be thoroughly trained, and shall from time to time undergo practices at a central station in the use of breathing apparatus and in rescue work, in accordance with a scheme approved by the Secretary of State.

KLINGER'S WATER GAUGE FITTING.

In water gauges as usually constructed the gauge glass, or the protecting casing which surrounds it, is rigidly connected to the heads of the gauge cocks. Those water gauges the glasses of which are surrounded by opaque protecting casings which are only provided with glazed sight slots, and particularly those water gauges whose glasses are provided with reflecting surfaces, have the disadvantage that in cases where the illuminating light rays do not fall perpendicularly through the sight slot in the casings or are not directed perpendicularly upon the reflecting surfaces, it is difficult, or even impossible, to properly observe the water level. In the arrangement illustrated, the invention of Mr. Richard Klinger, Gumpoldskirchen, Lower Austria, the gauge glass between the two cocks, or the gauge glass protecting casing, is mounted to rotate about its longitudinal axis, so that the glazed sight slot in the opaque protecting casing, or the reflecting surface, can be turned at any time directly towards the impinging rays of light, and the water level can always be properly observed.



Water Gauge Fitting.

Referring to the illustration, each of the two cock bodies A of the water gauge, of which only the lower one is shown, terminates in a short tube C which serves as a pivot for the corresponding end of the gauge glass protecting casing B. The end of the short tube C is provided with a flange D between which and the cock body proper the tube has fitted on it an externally screw-threaded sleeve E which is bored to fit the tube, and is made in two parts to facilitate being placed in position. This sleeve can rotate upon the tube C and is screwed into an internally screw-threaded recess F formed therefor in the end of the gauge glass protecting casing. When in place screwed in the recess F the end of the sleeve E presses the flange D of the short tube C firmly against a packing ring H arranged between the flange D and the inner end G of the recess in the gauge glass casing B. The arrangement is such that the gauge glass protecting casing can be easily rotated, and at the same time an efficient packing can be maintained between the end of the casing and the end of the short tube C of the cock body.

Engine-driver Fatally Scalded.—A fatal accident took place at Forres Station on the 20th inst., resulting in the death of an engine-driver, who at the time of the accident was at work below the engine repairing the boiler, when a plug blew out and he was so severely scalded that he subsequently died.

PIG STEEL FROM ORE IN THE ELECTRIC FURNACE.*

BY ROBERT M. KEENEY.

THE term "pig steel" has been defined by Dr. J. W. Richards, of Lehigh University as "a metal with 2·2 per cent. or less of carbon, a very small amount of silicon and manganese, low in sulphur and phosphorus, and made directly from ore in the electric pig-iron furnace." In chemical composition it is steel. The writer does not advocate the production of pig steel from ore in the electric furnace as a competitor of the present method of steel production with pig iron as an intermediate step, but presents the general metallurgical side of such a process and its economical possibilities in regions where power is cheap, and fuel and reducing materials are expensive, as, for example, Sweden, California, British Columbia, and the western coast of South America. If steel is the desired final product, it seems more feasible and cheaper to produce as pure a product as possible—pig steel—for any subsequent refining operations, rather than pig iron. This would prove to be the case for two reasons: (1) As has been found to be the case at Heroult, Cal., Domnarfvet, and Trollhättan, pig steel can be produced more cheaply in the electric shaft furnace than pig iron, because of the greater output per unit of electrical energy consumed. (2) Owing to the lower percentage of impurities in pig steel, 1 to 3 per cent., instead of 4 to 8 per cent. in pig iron, a greater output can be obtained from the final refining furnace at a lower cost.

A process to produce efficiently a metal conforming to these requirements should satisfy the following conditions: (1) As the product in order to be a steel must not contain over 2·2 per cent. carbon, it should be possible not only to keep the percentage of carbon in the metal below that amount, but it should also be possible to regulate the carbon within reasonable limits *i.e.*, control the composition of the metal. (2) The product should contain percentages of silicon, phosphorus, and sulphur either below the limit set by consumers of Bessemer and open-hearth steels, or at least low enough not to require prolonged refining in another furnace. (3) The loss of iron in the slag should not be excessive. (4) The furnace used must be adapted to continuous operation and the production of a large tonnage. (5) By the process it should be possible to produce pig steel at a greater profit than by existing methods.

Considering the possibility of the use of the electric furnace to satisfy these requirements: (1) As it is not necessary to introduce carbon for fuel in the electric furnace it is not necessary to have excess carbon in the charge beyond that needed for reduction, therefore no difficulty should be experienced in keeping the carbon of the product below 2·2 per cent.; and it should be possible to regulate the carbon within reasonable limits. (2) The temperature of the electric furnace can be regulated by the power input, so that very basic slags can be used, which should result in slagging of silicon, phosphorus, and sulphur. (3) While the loss of iron in the slag with an electric furnace running on pig steel would probably be greater than in the case of pig iron, owing to the weaker reducing atmosphere of the pig-steel furnace, it should not be so excessive as to prohibit the use of such a process under favourable economic conditions. (4) The electric shaft furnace has been proved to be easily adapted to continuous operation for pig-iron production, and should operate more uniformly on pig steel than on pig iron because there is not the tendency for carbon to accumulate in the furnace. (5) In localities where electric-furnace pig iron can be produced at a profit, pig steel for further refining could be made at a profit if the market demand was for steel.

Trouble was experienced at the Hardanger, Norway, electric pig-iron plant with coke as a reducing material. The failure of this plant has been assigned to the use of coke, because coke has a higher electrical conductivity than charcoal and hence not as much heat is generated by the resistance of the charge to the passage of the electric current. For this reason, trouble might be experienced, with a shaft furnace using coke as a reducing agent in the production of pig steel, but the problem will undoubtedly be solved eventually. The writer visited the Hardanger plant a few months before it was closed, and from observation of existing conditions does not believe the failure of the enterprise was entirely due to the use of coke.

J. Crawford says that at Heroult, while difficulty was experienced with coke alone as a reducing material, "by adopting certain precautions in crushing the stock and feeding the same into the furnace I have operated on a mixture of 60 per cent. coke and 40 per cent. charcoal with a very fair degree of furnace efficiency. I believe that many of our coals which make a poor metallurgical coke for blastfurnace use on account of their low crushing strength might be found to make a satisfactory fuel for electric furnace use."

The results at both Domnarfvet and Trollhättan indicate that pig steel can be made directly from ore in the electric shaft furnace. In these runs no attempt was made to produce pig steel, but the product contained from 1 to 3 per cent. carbon, as before stated. While it would undoubtedly be more difficult to regulate the carbon of the product in a shaft furnace operated continuously than in an intermittent hearth furnace, it could be done, but the regulation would not be so close.

The results of the experiments as to carbon are as follows: (1) In producing pig steel containing from 0·25 to 1·50 per cent. carbon for any particular furnace and basicity of charge, the carbon content of the pig steel can be regulated by varying the carbon in the charge. (2) An increase or decrease of lime in the charge causes a corresponding decrease or increase of carbon in the pig steel. (3) The use of fluorspar in excessive quantities causes a marked increase in the carburisation of the pig steel. (4) The experiments of Neveu and Arnou indicate that the carbon of reduction may be supplied from coke, anthracite coal, or charcoal, and the charge may be fine, coarse, or briquetted. (5) The work at Domnarfvet and Trollhättan shows the possibility of keeping the carbon of the product below 2·2 per cent. in an electric shaft furnace.

As to silicon, the experiments show in general that the percentage of silicon in the pig steel can be kept at a low figure if desired, and that its regulation is not difficult.

The conclusions as to phosphorus are: (1) Increased carbon in the charge causes an increase of the percentage of phosphorus in the pig steel, because of the stronger reducing conditions. (2) Increased basicity of the slag does not cause the slagging of more phosphorus if the slag is very thick. (3) If a small amount of fluorspar is added to thin the basic slag, the slagging of the phosphorus is assisted. (4) Continuous operation of the furnace does not increase phosphorus in the pig steel. (5) Owing to the more oxidising conditions in the electric furnace when pig steel is being made rather than pig iron, a greater percentage of the phosphorus is slagged.

And as to sulphur the conclusions arrived at are: (1) An increased reducing atmosphere aids in the passage of sulphur into the slag. (2) Increased basicity of the slag causes more of the sulphur to be slagged. (3) By thinning the slag a small amount of fluorspar assists in sulphur elimination from the pig steel, but an excess has the contrary effect. (4) Continuous operation of the furnace does not cause increased sulphur in the pig steel. (5) With a fluid basic slag, sulphur can be slagged readily in the electric furnace production of pig steel in both a continuous and an intermittent operation.

With steady operation in a large furnace, the loss of iron in the slag should not exceed 4 per cent. of the total iron charged, depending on the amount of carbon desired in the product, but if a pig steel containing less than 0·25 per cent. carbon is produced there will probably be a greater loss of iron in the slag.

An experiment was made, extending over several hours, to note the effect upon the pig steel of continuous charging and tapping rather than intermittent operation of the furnace. In addition to hematite, limestone, and coke, a small quantity of fluorspar was charged. A tapping was made about the middle of the run, which resulted in the following products: Pig steel, carbon 0·39, manganese 0·08, silicon 0·12, phosphorus 0·031, sulphur 0·048 per cent.; slag, SiO_2 30·48, CaO 31·30, MgO 13·39, FeO 15·20, Al_2O_3 9·28 per cent. The power consumption was 3,940 kw.-hr. per gross ton of pig steel. From the product it may be seen that as good a grade of pig steel can be produced in an electric furnace when operated continuously as when operated intermittently.

The results of electric furnace pig iron manufacture in

* Abstract of paper read before the American Institute of Mining Engineers, February 18th, 1914, and reproduced from "The Iron Age."

Sweden also show the feasibility of pig steel production in the electric shaft furnace, as regards carbon and impurities in the pig steel and loss of iron in the slag. J. Crawford remarks as a result of his experience at Heroult with an electric shaft furnace: "The matter of too little carbon gives less trouble, and if the furnace is producing low silicon and carbon iron should give none at all." From his results it appears that it is easier to operate the shaft furnace when making pig steel than when making pig iron. From the results available it seems that there should be no greater difficulty in the elimination of impurities from pig steel in a continuous shaft furnace than an intermittent operation.

In any place where there is a market for steel, and pig iron can be made at a profit in the electric furnace, it will be more profitable in the end to make pig steel for subsequent refining in an electric furnace or open-hearth, than to produce electric furnace pig iron with a subsequent refining to steel. This is true because the power consumption has been found to be lower per ton of pig steel than per ton of pig iron, and because the time necessary for refining is reduced, which results in a greater output at a lower cost.

The results of the early experiments at Domnarfvet show that the power consumption per ton of metal produced decreased as the amount of carbon charged per ton of iron was reduced. In the latest report of the engineers at Trollhättan, it is stated that the power consumption per ton of pig iron varies in proportion to the iron content of the ore. A poor ore and pig iron high in silicon and manganese require more power than a rich ore and pig iron low in silicon and manganese. This was also found to be the case in California. The results of the writer, of course, show a high power consumption because of the small size of the furnace.

Among other expenses of pig steel production, maintenance and capital charges would be about the same as for electric furnace pig iron production. The labour cost per ton of product would be a little lower for pig steel. The electrode consumption per gross ton of pig iron has been reduced to 6·7lbs. It might be a little higher in making pig steel, because of there being less carbon in the charge, but it should not exceed 15lbs. per ton of pig steel.

The use of pig steel in the open-hearth was tried out at Degerfors, Sweden. It was found that pig steel produced by the electric shaft furnace was more suitable for steel making in the open-hearth than ordinary pig iron, and required less time for complete refining. Normal pig iron made in the electric furnace was found to be less suited to the production of open-hearth steel than normal blastfurnace pig iron. This shows the advantage of production of pig steel rather than pig iron in the electric furnace when steel is to be the final product.

GENERAL SUMMARY.

(1) In the electric furnace production of pig steel from ore, carbon in the product can be kept below 2·2 per cent., and regulated to an extent by the amount of carbon charged, without resulting in excessive loss of iron in the slag or in the production of a pig steel very high in impurities, if a fair grade of ore is used.

(2) It is not difficult to slag the greater part of the silicon, phosphorus, and sulphur of the charge, if the furnace is hot and the slag fluid, but conditions are less favourable to the slagging of sulphur than of other impurities in the operation of an electric furnace for pig steel production, which is, of course, contrary to experience in the manufacture of pig iron.

(3) The loss of iron in the slag should not be excessive unless the pig steel produced is of very low carbon content.

(4) From the results with the Domnarfvet, Trollhättan, and Heroult furnaces, there does not appear to be great difficulty attending the production of pig steel in an electric shaft furnace, and in fact experience has shown that there is less difficulty in the operation of the electric furnace on pig steel than on pig iron.

(5) At any place where there is a market demand for steel, and pig iron can be made in the electric furnace at a profit, the steel ultimately produced would be cheaper, if made by the electric reduction of iron ore to pig steel, followed by refining in another furnace if necessary, than if the product of the electric reduction furnace was pig iron to be subsequently converted to steel in another furnace.

THE OPERATION AND UPKEEP OF ELECTRIC MOTORS.*

BY E. F. BUTLER.

THE objects of maintenance are twofold: first, to run the plant with as few stoppages as possible, and secondly, to do so without excessive cost. To get the best results, the upkeep of the plant should be considered before it is installed, and it should be laid out with the objects kept in view of suitability, accessibility, the minimum number of sizes, and everything possible standardised so that the smallest number of spare parts and replacements need be stocked.

A large number of shops belonging to a certain firm were changed over to electric driving by degrees, the process extending over several years. Motors were bought one or two at a time, and, in some cases, simply replaced existing engines. As a result they have over 30 motors, seven of which are over 50 h.p.; out of 26 motors, there are 19 different sizes and nine different makes. If, at the outset, plans had been made to drive the whole of the works, and a modified group drive adopted, a lot of shafting and old-fashioned gearing would have been eliminated, and only about five sizes of motor would have been necessary. The additional first cost would probably have been recovered in less than three years.

In this case, the cost of upkeep is high, as there are too many sorts of motors to keep any spare parts, and so the running of the plant depends entirely on the personal element. One of the best installations from a maintenance standpoint, that is, plant laid out with the object of economical operation and upkeep, is a riverside warehouse handling peas, beans, grains, &c. These are conveyed, sorted, washed, dried, split, and sacked. On deciding to go in for electric driving, the owner hired a motor and a recording ammeter. He spent six months in experimenting, and at the end of that time knew exactly what he wanted. As a result there are only three sizes of motors used, all well above their work, and one size of brush fits any motor in the place. Similarly, one of the biggest printing works in London has 130 motors with only four sizes. A spare motor and starter of each size are kept in stock; the complete motor or starter is changed, which takes under half an hour, and the repair is done properly in the workshop.

As one object of maintenance is to prevent breakdowns, an analysis of 100 breakdowns may be given. Thirty-eight were on motors and 62 on control gear.

Of the motors three had damaged shafts, one being broken, one bent, and in one case the armature was loose on the shaft. Six machines had bearing or lubrication troubles, namely, four throwing oil, one hot bearing, and one bearing seized. Fourteen stoppages were due to brushes, brush gear, or commutator troubles; in five cases the brushes were worn out, in three cases they were sticking from dirt, in two cases the motor had flashed over due to dirty commutators, in two machines the insulation of the brush spindles had broken down owing to dirt, one machine had the holders loose on the spindle, in the remaining one the wire had become unsoldered in the thimble.

Nine motors had winding troubles, two being burnt-out field coils, four burn-outs were on armatures, in one case the shunt winding was in contact with the compounding, in another the end was knocked off a field coil during cleaning, and in one case there was trouble owing to bad connections between the lugs on the commutator and the ends of the armature coils.

Six were miscellaneous faults and included one earth on terminal box, two armature bands off, one pole piece loose, one wrongly connected, and one had the key out of pinion.

The 62 breakdowns on the control gear were made up as follows:—

Twenty-eight on starters, which included 14 contacts or segments burnt, seven resistances burnt out, three handles broken, one arm loose in slate, one no-volt coil burnt out, one arm sticking in full-on position, and one arm not holding up owing to contacts on overload coil not dropping.

Sixteen on fuses; in five cases the fuses had simply blown and were replaced; in the other 11 damage was done usually by bare fuses arcing on to the metal case

Ten on switches, about half being bad contacts or arcing to cover; the remaining half more or less fell to pieces.

The remaining eight were miscellaneous and comprised the

* Abstract of an informal paper read before the Junior Institution of Engineers, February 27th, 1914, and reproduced from the "Electrical Review."

failure of one shunt-breaking resistance, four circuit breakers gave out, in one case the end burnt off the coil, two had burnt contacts, and one was fixed upside down, one starter was condemned by the Home Office and replaced, and two installations had faults on the wiring. Out of a hundred breakdowns, 12 can be considered unavoidable, 17 were overcome by some alteration or modification, and the remaining 71 were due almost entirely to neglect or ignorance in other words, to lack of maintenance.

The following points should be kept in mind when selecting a motor: The commutator should be of generous size, to allow for trueing up several times. The segments should be of hard copper, insulated only with pure mica; micanite should be avoided. The ends of the armature coils should be brought down and soldered directly to the commutator segments. The bands which hold the coils in the slots should not increase the diameter of the armature at all. The stampings under the band should be smaller than the remainder, so that the band comes flush with the surface. This lessens the chance of its coming off, and by not interfering with the clearance gives the bearings a longer life.

The next point to look to is the brush gear. The rocker should be in two pieces so as to allow of its removal if necessary. The insulation of the spindles should be of mica, and the spindles themselves of brass and large enough in diameter to prevent vibration or chattering. The connections from spindle to spindle in machines of more than two poles should be of rod or strip taped and enamelled, and preferably arranged one on the face of the rocker and one on the back to avoid any possibility of them short-circuiting.

In shunt machines it is sometimes an advantage to have the leads to the brush-holders long enough to enable the motor to be reversed by moving the rocker. The holders themselves should be of the type in which the brush slides in a box and is pressed down by an adjustable spring. A screw should be provided to take the end of the flexible connection to the brush, and so prevent the current from passing through the spring; this screw should not be the screw that clamps the holder on to the spindle. It should be possible to remove the holders from the spindle without disturbing anything else. The holders should be so constructed that nearly all the brush can be used up. For ordinary work the bearings should be of hard brass. White metal can be used, but requires more supervision. For the heaviest work it is worth while going to a little more expense and using phosphor bronze. In all except the smaller sizes, two oil rings working in separate grooves should be provided. The oil well should be large and painted internally. This provides against any sand being left inside. The cover of the oil well should be hinged and fitted with a spring; this will ensure its being closed. Covers that are loose or hung on pieces of chain usually get lost, and dirt gets in. The overflow should be large enough to carry away excess oil as fast as it can be put in with a pint feeder. The best type of overflow is the one in which a piece of pipe is screwed through the bottom of the oil-well to the right height; the surplus oil then drops clear and does not trickle down the sides of the frame. All field coils should have terminal blocks or connectors to facilitate disconnection for testing. It should be possible to remove the armature from either end of the machine. Any covers that may be fitted should be capable of being put on or taken off while the machine is running, without the possibility of touching live metal or dropping screws or bolts inside. In the case of belt drives slide rails should be provided, and the ends of these should be open. Some makers use square or tee-headed bolts to hold the motor down with nuts on top. A better plan is to have square nuts inside the rails and use setscrews, then if the motor has to be slewed round or moved it can be easily done, otherwise it is necessary to pack up the motor clear of the holding-down bolts and slew it on the packing. The best way to fit a pulley is to fit it up to a shoulder on the shaft with a feather key, tap out the end of the motor shaft and fit a setscrew and a circular plate larger than the shaft. This method is particularly necessary with ball-bearing motors, as the pulley cannot be knocked or wedged off without damage.

(To be continued.)

Wireless Telephony at a Colliery.—The Fife Coal Company have introduced wireless telephony apparatus into their Lindsay Colliery at Kelty. If successful, it will be put into operation at all the collieries of the company.

INDUSTRIAL AND TRADE NOTES.

Machine Tool and Engineering Association, Ltd. This Association has arranged to hold an Exhibition at Olympia, London, from Thursday, September 28th, 1916, to Wednesday, October 18th, 1916, both days inclusive.

Change of Address. Messrs. Wailes, Dove, & Co., Ltd., of Newcastle-on-Tyne, inform us that they have taken larger offices at Channel Chambers, James Street, Cardiff. Their representative, Mr. T. I. Forward, and his assistant, Mr. T. J. O'Leary, will continue to look after their interests.

Employment in the Engineering Trades. According to the Labour department of the Board of Trade employment showed no marked change as compared with February, and was still good. There was some falling off in iron and steel manufacture, but the engineering, and shipbuilding trades continued busy. Compared with the high level in March, 1913, employment generally showed a decline.

Aluminium-Ore Production of the United States.—According to W. C. Phalen, of the United States Geological Survey, the production of bauxite or aluminium ore in 1913 showed a steady increase. The output was 210,241 gross tons, valued at $997,698, an increase of 31·5 per cent., and 29·8 per cent., respectively, over the figures for 1912. The average price of bauxite per gross ton at the mine for 1913 was $4·75, which differed by only a few cents from the prices recorded for the three previous years.

The Battle of the Gauges in India.—In a recent lecture, Sir Guilford L. Molesworth said that India had committed the grave mistake of introducing a break of gauge in the network of their railways. The battle of the gauges in India extended over an area of at least one and three-quarter million square miles, and affected a population of some 260,000,000. There were now in India 8,266 miles of standard gauge (5ft. 6in.), 14,750 miles of metre, and about 3,000 miles of 2ft. or 2ft. 6in. gauge railway. The only practical course was to minimise the evil by restricting the narrow gauge as far as possible to defined areas, and though the problem presented enormous difficulties the attempt to solve it should be made without delay, as every year increased the evil.

Trade Unions in the United Kingdom.—A paper issued a few days ago by the director of the department of Labour statistics, states that the total number of trade unions in the United Kingdom at the end of 1912, so far as known to the department, was 1,134, of which 539 were registered under the Trade Union Acts, and 595 were not so registered. The Unions with a large membership, however, were for the most part registered, the average membership of the unregistered unions being only about 1,100, as compared with nearly 5,000 for registered unions. The number of trade unions shows a reduction of 59, or 5 per cent. as compared with 1911. The number has been declining since 1896 (the maximum year) in consequence of amalgamations and of the absorption of smaller unions. The membership on the other hand has shown an almost uninterrupted increase. The total membership at the end of 1912 was 3,281,003, showing an increase of 8·8 per cent. over 1911, which itself showed an increase of 23·4 per cent. over 1910. The aggregate membership has more than doubled since 1896.

Mineral Output of Great Britain.—The Home Office, on Saturday last, issued an advance proof (subject to correction) of the tables relating to the output of coal and other minerals in the United Kingdom, and the number of persons employed at mines during 1913. The document shows that the output of coal from mines under the Coal Mines Act, which was 260,398,578 tons in 1912, rose last year to 287,411,869 tons, an increase of 27,013,291 tons. The total is the highest on record. There was a total of 1,127,890 persons employed at mines under the Coal Mines Act, an increase of 38,800 on the previous year. The increase in the output of coal is at the rate of 10·37 per cent., and the increase in the number of persons employed at the rate of 3·56 per cent. The output of some of the principal minerals, other than coal, under the Coal Mines Act, were, clay and shale 457,244 tons, fire clay 2,585,763 tons, ironstone 7,709,624 tons, oil shale 3,280,143 tons, sandstone 144,923 tons. Under the Metalliferous Mines Regulation Act, the total output of minerals in 1913 reached 3,236,283 tons, as compared with 3,024,621 tons in the previous year. The total last year included 1,881,853 tons of iron ore, 356,316 tons of limestone, 214,573 tons of rock salt, 238,494 tons of gypsum, 133,984 tons of clay and shale, 95,271 tons of slate, 89,718 tons of sandstone, and 17,294 tons of zinc ore. There was a total of 27,412 persons employed in these mines, as against 28,058 in 1912. It is pointed out that large quantities of several important minerals are obtained from quarries under the Quarries Act, and from other open workings the returns for which are not yet available.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1912.

Tandem compound internal-combustion engine. Wintle. 19795.
Steam traps. Brooke. 29993.
Pulley blocks and hoisting and lowering gear. Tabulo. 30094.

1913.

Gas-driven pumps. Tooley. 7273.
Rotary pumps. Hammer. 7464.
Valve mechanism. Mellersh-Jackson. 7495.
Measuring taps or valves. Odet. 7573.
Railway signalling apparatus. Forse & Spiller. 7582.
Rotary valve mechanism for internal-combustion engines. Soc. des Etablissements Malicet et Blin. 7590.
Railway motor-cars. Baguley. 7665.
Turbine pump or compressor. Lawaczeck. 7783.
Internal-combustion turbine, applicable also as a steam turbine. Flower, Bradley, & Wichmann. 7821.
Apparatus for determining quantities of gas. Binz. 8042.
Water meters. Nash. 8104.
Gas-producers. Hart. 8126.
Vacuum gauges. Scanes. 8170.
Easy starting device for internal-combustion engines. Pybus and Pybus. 8202.
Driving or conveyer belts. Turner & Turner. 8636.
Automatic combined lever brakes for pit cages and hoists. Parkes and Parkes. 8897.
Rotary engines, motors, air-compressors, and pumps. Hodges. 8991.
Change-speed gear for motor vehicles. Lanchester. 9427.
Throttle-valves for internal-combustion engines. Pentony, and W. H. Dorman & Co. 9694.
Driving belts. Thompson. 10109.
Auxiliary air inlet valves of internal-combustion engines. Whalley. 10238.
Air-admitting means for internal-combustion engines. Wilson. 10520.
Internal-combustion motors. Médinger. 10666.
Rail-bending apparatus. Vojacek. 10686.
Operation of cooling iron or steel bars preparatory to rolling into sheets. Morgan & Davies. 10878.
Indicating and recording apparatus for hydraulic presses. Schuch. 11011.
Variable-speed gearing. Alexander. 11566.
Valve arrangement for internal-combustion engines. Robertson. 12006.
Steam generators. Makin & Makin. 12009.
Means for supplying air to boiler furnaces. McKee, Powers, and Tait. 12096.
Valve mechanism of internal-combustion engines. Bellamy. 12459.
Motor vehicles. Ainsworth. 12842.
Driving belts. Feuge-Renforth. 13322.
Temperature-determining devices. Heathcote, and Rudge-Whitworth, Ltd. 13875.
Regulating superheat in connection with steam-generators. Babcock & Wilcox, Ltd., and Rosenthal. 13971.
Percussive tools for scaling tubes. Brindley, and Boiler Scalers, Ltd. 14102.
Hydraulic hoisting machinery. Sir W. G. Armstrong, Whitworth, and Co., and Murray. 14129.
Automatic controlling appliances for air compressors. Wilson, and Tilghman's Patent Sand Blast Company. 14554.
Apparatus for the generation of water gas. Stephenson. 15677.
Means for supplying auxiliary driving fluid to internal-combustion engines. Letombe. 15781.
Internal-combustion rotary engines. Tygard. 17377.
Regenerative gas furnaces. Siemens. 17956.
Turbines. Fottinger. 18006.
Burners and burner fittings for furnaces. Muers. 18033.
Facing chucks for surfacing, boring, and milling machines. Kearns, Burton, and H. W. Kearns & Co. 19066.
Milling cutters and circular saws. Smith. 21297.
Film-lubricated thrust bearings. Michell. 21557.
Rotary-valve mechanism for internal-combustion engines. Pazos. 21729.
Clutching or coupling device. Schweinfurter Pracisions Kugel Lager-Werke, Fichtel, & Sachs. 22145.
Automatically controlling the supply of air to boiler furnaces. Frére. 23018.
Piston packing rings. Carlisle & Harbord. 23369.
Wrenches. Kadow. 24423.
Steam-boiler settings. Babcock & Wilcox, Ltd. 24532.
Hydraulic compressor. Davey. 25065.
Valve for automatically stopping the supply of liquid to pipes upon breaking of the latter. Meier. 26572.
Pneumatic elevators. Mitchell, and Henry Simon, Ltd. 26694.
Valves. Georg Niemeyer. 27046.
Process for briquetting iron ore. Crusius. 27536.
Apparatus for heating water. Wilkinson. 28847.
Method of covering or armouring electric conductors with metal. Chase. 29028.

1914.

Compression and priming taps or valves for internal-combustion engines. Langdon, and Ross Courtney & Co. 938.

ELECTRICAL, 1913.

Automatic regulators for electric supply systems. Kettering 7544 and 7546.
Dynamos. Peugeot. 7840.
Driving of looms by electric motors. Siemens Schuckertwerke Ges. 7842.
Incandescent electric lamps. Beckwith. 8124.
Dynamos. Mason. 8128.
Mercury vapour lamps. Heinmann. 8172.
Arc lamps. British Thomson-Houston Company. 8416
Electrical connectors of the plug and socket type. Lundberg, Lundberg, Lundberg, & Pegg. 9460.
Ampere hour meter. Allgemeine Elektricitats Ges. 9503.
Controlling of electric motors for ship propulsion. Siemens Schuckertwerke Ges. 13148.
Electric switches. Lucas & Handley. 13721.
Apparatus for closing and interrupting electric currents. Poulsen. 14034.
Electric-light fittings. Lucas & Veritys, Ltd. 14170.
Cooling of dynamos. Akt.-Ges. Brown, Boveri, et Cie. 14941.
Electric lamp holders. Day. 15318.
Electric switches. Lucas & Lucas. 16885.
Electric-circuit closing devices. Siemens Schuckertwerke Ges. 17532.
Means for operating electric switches from a distance. Siemens Brothers Dynamo Works, Ltd., Lydall, and Brooks. 20870.
Apparatus for electrically smelting metal. Guggenheim. 23004.
Electrical protective systems. Waters. 25274.
Collector-brush holders for electrical apparatus. Christie. 25464.
Relay arrangements for the automatic control of electric circuits. Siemens-Schuckertwerke Ges. 27824.

1914.

Commutators for electricity meters. Elster. 5365.
Electrodes. Fried. Krupp Akt. Ges. 6055.

METAL QUOTATIONS.

TUESDAY, APRIL 21ST.

Aluminium ingot	86/- per cwt.
,, wire, according to sizes, &c. ......from	112/- ,,
,, sheets ,, ,, ... ,,	112/- ,,
Antimony	£27/10/- to £29/10/- per ton.
Brass, rolled	7¼d. per lb.
,, tubes (brazed)	9⅝d. ,,
,, ,, (solid drawn)	8d. ,,
,, ,, wire	7⅜d. ,,
Copper, Standard	£64/2/6 per ton.
Iron, Cleveland	50/7½ ,,
,, Scotch	56/7½ ,,
Lead, English	£18/10/- ,,
,, Foreign (soft)	£18/2/6 ,,
Mica (in original cases), small	6d. to 3/- per lb.
,, ,, ,, medium	3/6 to 6/- ,,
,, ,, ,, large	7/6 to 11/- ,,
Quicksilver	£7/-/- per bottle.
Silver	26 15/16d. per oz.
Spelter	£21/10/- per ton.
Tin, block	£160/15/- ,,
Tin plates, I.C.	12/10½ per box.
Zinc sheets (Silesian)	£24/15/- per ton.
,, (Stettin; Vieille Montagne)	£25/2/6 ,,

Trailer Trams for London.—The London County Council's application to the Board of Trade for permission to run further trailer tramcars on its system has, we learn, been successful, the Government Department having authorised the running of trailers on several additional routes in South London.

The Mechanical Engineer.
An Illustrated Weekly Journal Vol. 33, No. 849.

Edited by
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Telegrams: "Scientific," Manchester.
Telephone No. 6655 City.

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Unification of London Electricity Supply.

The report by Messrs. Merz and McLellan to the London County Council on the present position and future development of electricity supply in London, though concerning Londoners primarily, is of interest to other large urban centres, as it serves to illustrate not only the extent to which unification of control and concentration of power production determine the economic distribution of electrical energy, but also the extent to which lack of such unification leads to inefficiency and waste. The Metropolitan Police area, which includes what is known as Greater London, is at present supplied with electrical energy by 65 authorities from 70 generating stations, each averaging 4,400 kw., and using altogether about 560 engines each averaging 550 kw. and generating electricity on 49 different systems, the total plant and machinery used in these undertakings costing on the average about £26 per kilowatt. Viewed in the light of present practice, this summary of the means by which London's demand for electric power is met seems woefully inefficient and behind the times, and, could the production and distribution of electrical energy in the area named be treated by the engineer as a virgin problem, enormous economies could be easily effected. But, like Topsy, London's electrical requirements and methods of supply have "growed," and the question is how can the present inefficient system, or rather want of system, be best improved, in view of existing rival authorities and vested interests, for it is these which make the question difficult. The economical production of electricity is inseparably associated with large power units, and how greatly London is behind in this respect is evident on comparison with other cities, where units of machinery up to 30,000 kw. at a cost of £7 to £8 per kilowatt are used, as against 550 kw. at a cost of £26 per kilowatt in London. Any method of reform-

ing existing production and distribution, to be satisfactory, must inevitably take into account future requirements as well as present needs, while low cost is impossible without a heavy load factor. Estimates of the one, or the best means of securing the other, are matters on which there is room for wide difference of opinion, so that it is scarcely to be expected that Messrs. Merz and McLellan's views will pass unchallenged. Their statement, for instance, that the greatest improvement in the load factor in the near future will be obtained from the addition of cooking and heating load as a result of diminished cost will certainly not be universally accepted, while many will regard their statement that 20 times the present output of the lighting undertakings is a conservative calculation of London's requirements in the near future as unduly optimistic. Apart, however, from the difference of opinion which must inevitably exist where probabilities have to be taken into account, it is interesting to consider the recommendations they propose and the economic conclusions arrived at. Two ways of effecting important economies are suggested and discussed. One is to allow the extension of 8 or 10 of the best existing stations and gradually abandon all the others. The other is to aim at the gradual abolition of all the stations in or near the metropolitan area and the concentration of production of electricity for all purposes on sites situated on the river and well outside the city. The arguments in favour of the first plan are that it would be easier to carry out a more radical change and that it would save in cost of transmission ; while those in favour of the second—the policy recommended—are, (*a*) that it would effect a saving in cost of production more than sufficient to balance the increased cost of transmission ; (*b*) that it would allow unlimited room for expansion and possible by-product work ; and (*c*) that it would gradually remove fuel consumption from London. If the second alternative policy were adopted, the authors of the report estimate that the savings in working costs which existing undertakings could effect by obtaining their current from such a concentrated plant supplying for all purposes would be not less than 18 per cent., or about £170,000 a year, after allowing for all capital charges on new plant and mains. Further, that the initial capital outlay required for the purpose, allowing for growth of demand during the next four years, would be between six and seven millions sterling. This, of course, would be quite apart from the capital which would be extinguished by the abolition of existing plants, and which, it is estimated, could be written off, by the yearly saving coupled with present sinking funds, by 1931. Comparing the policy recommended with its alternative, they point out that to supply the general domestic demand from 10 model stations on any of the present sites would cost at least 20 per cent. more than from plant concentrated on the river, and that if the comparison be made not with 10 new stations, but with 10 of the best existing stations rearranged, the policy of extending on existing sites would show to still less advantage. These figures of the relative advantages and disadvantages have doubtless been carefully worked out, though the details on which they are based are lacking in the report, and possibly their presentation might lay the conclusions open to criticism. It is impossible, however, to peruse the report which has been presented without being impressed with its thoroughness, and also with the fact that the production and distribution of electrical energy in London is sadly in need of overhaul and greatly behind that of other leading cities.

Institution of Mechanical Engineers.—At the anniversary dinner of this Institution, held on the 23rd ult., in London, the President (Sir H. F. Donaldson) stated that amongst the plans for the future was the issue in June of an Institution journal and the discussion in the provinces of papers read in London.

DESIGN OF STEAMSHIPS FROM THE OWNER'S POINT OF VIEW.*

BY L. PESKETT.

TWENTY-ONE years ago the principal ships of the Cunard Company were propelled by single screws, the engines being of the triple-cylinder compound type. In 1893 came the twin-screw steamers "Campania" and "Lucania" with triple-expansion engines. In 1905 twin-screw steamer "Caronia," quadruple-expansion engines. In 1905 triple-screw steamer "Carmania," compound turbine engines. In 1907 quadruple-screw steamers "Lusitania" and "Mauretania," compound turbine engines. In 1914 quadruple-screw steamer "Aquitania," triple-expansion turbine engines. In 1914, building, twin-screw steamers "Transylvania" and "Aurania," compound geared turbine engines.

The effect of the owner's experience on the design and construction of any new vessel is mainly felt in the demand for easy and inexpensive flexibility of arrangement and power. The evolution of the design must, in fact, be developed from the owner's experience and data, if the finished ship is to prove a successful commercial asset. A builder may produce a vessel possessing every virtue as regards perfect material and finish, but the material may not be so arranged as to prove a source of profitable revenue on the trade for which the ship is intended. Most shipowners now employ a technical staff who can determine the features of new designs, and, this being so, they should take upon themselves a considerable burden of responsibility, and avoid imposing strict guarantees upon the builder. This will effect a reduction in first cost, for the builder, if he is confronted by heavy penalties, must protect himself by increasing the cost to the owner.

Generally speaking, the owner has access to a mass of data which will guide him in dealing with the preliminaries of new designs.

The Turbine Committee was constituted by the Cunard Company in August, 1903, for the purpose of enquiring into the advisability and practicability of adopting turbine machinery in steamers. The amount of information amassed ultimately led the company to their decision to install engines of this type. While on the subject of turbines, attention may be drawn to the bold experiment made by the Cunard Company in building two ships of equal dimensions and displacements — the "Caronia" and "Carmania" — one fitted with reciprocating engines and the other with turbines. The boiler power in both ships is identical ; the forms are as nearly alike as it was possible to make them. The "Caronia," fitted with quadruple-expansion reciprocating engines, is propelled by twin screws, running at an average of 80 revs. per minute. The "Carmania," fitted with compound turbine engines, is driven by triple screws, running at an average of 175 revs. per minute. These ships have now been on service for over eight years, and the results do not warrant the adoption of direct-acting turbines to drive a ship of this type at a speed of 18 knots, the coal consumption for the "Carmania" being considerably greater than that of the "Caronia."

The mass of data which became available after the "Lusitania" and "Mauretania" had been on service for some years made the problem of designing the "Aquitania" one of comparative simplicity. The problem was that of designing a third ship, capable of working with the above on the mail service to North America. This new ship had a different financial outlook from that of the "Lusitania" and "Mauretania," as these latter each receive a substantial subsidy, and the company wished to possess in the third vessel one which would make as much per voyage without a subsidy as the express steamers were making with one. This involved the construction of a ship which could sail regularly from either terminal port once every three weeks, and unless an expensive rush is to be experienced at the termini, such a vessel should not take longer than 5½ days on the voyage. A speed of 23 knots was decided upon as being the most desirable for such a purpose.

The problem thus became to design a vessel which, travelling at 23 knots, could earn the greater profit aimed at. The alteration in speed meant a reduction in the cost of coal, to which had to be added lessened running expenses and a gain

* Abstract of paper read at the spring meetings of the fifty-fifth session of the Institution of Naval Architects, April 3rd, 1914.

in cargo deadweight. It was evident that to obtain sufficient revenue from passengers to make up the remainder of the sum aimed at, the new ship would require an additional deck over and above the number on the "Lusitania" and "Mauretania." In the preliminary calculation an effort was made to introduce this deck without adding materially to the total depth of the ships already constructed. The result was not satisfactory; the deck was added with an increase of depth, and it was seen that the beam would have to be correspondingly increased to give the necessary stability.

When viewed from the owner's standpoint, the problem of economical propulsion is one which assumes a different aspect from that which it possesses when subjected to the criticism of the purely scientific experimenter. Naturally, the owner will embrace any economy that can be offered to him. But economical propulsion is not merely a matter of obtaining an economical prime mover. There is a balance-sheet to be considered and economical credits must be balanced against their derivative debits. Take, for example, the economy of a quadruple-expansion engine over a triple-expansion engine of equal power. There will undoubtedly be a fuel economy, but there will necessarily be a larger engine. It would not, however, be wise to adopt a quadruple expansion set without a careful auditing of the pros and cons. The fitting of the quadruple type would save coal, but it would involve reducing the cargo capacity, for the engine-room would have to be lengthened to make room for the extra cylinder and crank, and initial cost, weight, and upkeep would all be increased. These might more than absorb any economy resulting from the machinery, or from saving bunker space no longer required. It has been found that unless the distance between the coaling ports exceeds about 2,000 miles, there is no advantage in fitting quadruple instead of triple-expansion engines, when all the elements of cost, weight, consumption of fuel, depreciation, upkeep, and other incidentals are taken into account.

In fitting combination sets of reciprocating engines and turbines in cargo steamers where the turbine has to be placed abaft the reciprocating engines, the loss of cargo space cannot be compensated for by the additional economy in machinery. In cases where the ship has sufficient beam to allow of the reciprocating engines and the low-pressure turbine being placed abreast, an ultimate economy can often be effected, although here also the additional shaft tunnel reduces the cargo capacity. A further disadvantage of placing the turbine between the shafts abaft the reciprocating engine-room is due to the ventilating hatch overhead. It is obvious that the advantages gained by increased economy in machinery may not counteract the loss in cargo capacity and in revenue that might be obtained from cabins if fitted in those spaces occupied by the machinery casings which pass through deck after deck. If the same power could be put into three or four turbines abreast with only one or two hatches over them, the chances of net economy being effected would be enhanced.

The Cunard Company have experimented with Herr Frahm's tanks on the "Laconia," and it has been shown without question that in that particular instance they have resulted in a reduction in the amplitude of rolling amounting to an average of 60 per cent. In the case of ships of the proportions of the "Aquitania," rolling is a feature to be avoided by every possible means. The great beam of such vessels increases the actual amount by which passengers berthed near the shell of the ship are alternately raised and lowered as rolling takes place. The "Aquitania" is therefore being fitted with anti-rolling tanks, and bilge keels have been dispensed with, and there is no doubt this experiment will be watched with much interest.

OGDEN'S STEAM DRYER AND OIL SEPARATOR.

THE accompanying illustrations, Figs. 1 and 2, show sectional views of a steam dryer and oil separator, the invention of Mr. J. E. L. Ogden, Lincoln Drive, Liscard. The arrangements comprise a plurality of curved slotted tubes of relatively small bore having scraper edges projecting therein, the parts being so disposed that the steam passing through the tubes is directed against the slots and against the scraper edges so as to cause the separation therefrom of the liquid contents.

The steam dryer shown in Fig. 1 consists of an outer casing A and a nest of tubes B of curved form, the tubes being held in two plates, one of which is firmly secured in position whilst the other is capable of movement within the casing. The free or loose tube plate is at the inlet end of the tubes and is suitably inclined so that any liquid which may lodge thereon flows to its lower end, where it can pass beneath the plate edge to a collecting sump F. The curved tubes have each a series of slots G therein at right angles to the tube axis, and adjacent to each slot and in the side thereof remote from the tube inlet, the metal of the tube is pressed inwards as at H so as to offer a sharp edge to the steam passing along the tube. The slots G and scraper edges H are on the outer side of the tube, so that as the steam rushes through

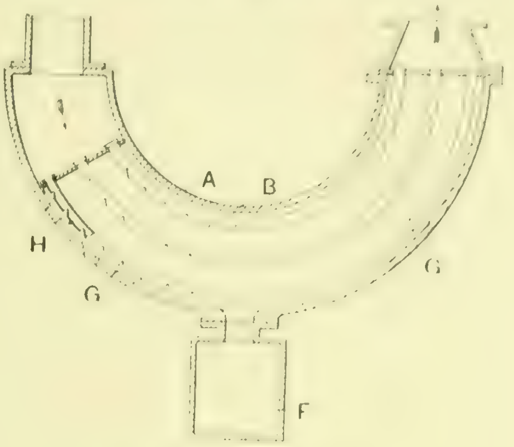


FIG. 1. OGDEN'S STEAM DRYER.

the tube it will, as its direction of motion is changed by the tube, impinge upon the edges and be deprived of any liquid held in suspension, the latter tending, on account of its weight, to pass out of the tubes through the gaps. It will thus be seen that the steam in its passage through the curved tubes is subjected to the action of the successive scraper edges which deprive it of its liquid contents. The latter falls into a sump at the bottom of the dryer casing from which it may return by gravity to a boiler or be expelled by a steam trap. As the pressure in the dryer casing A is the same as, or slightly in excess of, that in the tubes B, due to the kinetic energy of the jets at the tube gaps, the steam will not circulate in the casing, but will be confined to the tubes. Thus contact between the steam passing through the dryer and the liquid which has been separated therefrom by the tubes is obviated. The dryer casing may be of U shape for insertion between vertical pipes, as shown in Fig. 1, or may be adapted for insertion in a horizontal pipe range. It may also be fitted in the steam space of a boiler.

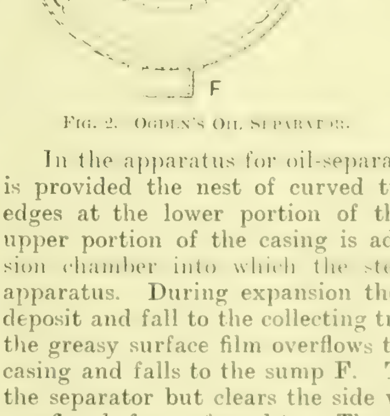


FIG. 2. OGDEN'S OIL SEPARATOR.

In the apparatus for oil-separating purposes, Fig. 2, there is provided the nest of curved tubes B having the scraper edges at the lower portion of the separator casing. The upper portion of the casing is adapted to act as an expansion chamber into which the steam issues on entering the apparatus. During expansion the oil particles in the steam deposit and fall to the collecting trough J. From this trough the greasy surface film overflows to the sides of the separator casing and falls to the sump F. The trough J extends across the separator but clears the side walls so as to permit of the overflow before referred to. The steam after passing through the expansion chamber travels through the tubes B and is there acted upon by the scraper edges against which it is projected whilst its direction of motion is being changed.

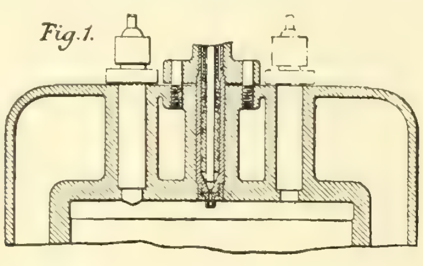
HIGH-POWER DIESEL ENGINES: THEIR DEVELOPMENT FOR MARINE SERVICE.*

BY JAMES RICHARDSON, B.SC., A.M.INST.C.E.

THE present time would appear to be opportune for a review of the past achievements of the Marine Diesel Engine, so that a due consideration of those performances and a full realisation of the failures may throw light along the lines of development in the future towards increase of power per unit and the standardisation of a type more suitable to meet marine conditions. The force of such discussion at the present moment cannot be questioned since there is no doubt that the marine oil engine, in its progress, has passed through the first phase of its evolution and is at present at a comparative standstill awaiting the application of the lessons of past experience.

So far, it is true that the Diesel engine has not justified the glowing and glorious anticipations of the many enthusiasts who were attracted by this prime mover. Early prophecies were much too sanguine, and the main reasons for the non-fulfilment of the expectations may be briefly summarised, as follows: (1) Theoretical considerations, apart from foundry work, were given, as is frequently the case with Continental engineers, pre-eminence in comparison with those practical factors which must be of the most vital importance where marine work is concerned. (2) On account of the economic conditions abroad the oil engine was largely developed for land purposes, and, due to the aforesaid optimism and without reference to the opinions of marine engineers, land engines were applied to marine work without the necessary modifications. (3) Over ambition led to the increase of the sizes of the unit without sufficient knowledge of the many difficulties

Fig. 1.

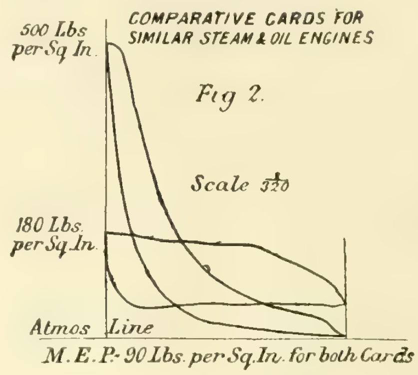


which are intensified out of all proportion to the increase of power per unit. (4) The failure of constructors to realise fully the importance of, and to apply practically, scientific experimental work and research.

Generally stated, these may be said to be the main causes of the retardation of the progress of the Diesel engine for marine propulsion. It might be inferred that success has not been achieved, but such a conclusion would be entirely erroneous. There are firms who, in the application of the marine Diesel engine, have so far been entirely successful. The question may well be asked why such firms have done so well. The reason is not far to seek. Primarily, they have been marine engineering firms. Secondarily, they have been careful and conservative. To particularise, the cycle of operation to which they have rigidly adhered has been the four-stroke cycle. Increases of power have generally been attained by adding to the number of separate units rather than by risking the disproportionate augmentation of difficulties consequent upon an increase in size of unit. Price has not been cut, weight has not been sacrificed, simplicity has not been forced, and the result has been success.

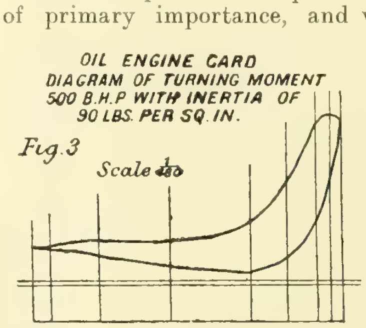
The well-known advantages of the oil engine for warship propulsion—the saving in weight, space, fuel, engine-room personnel, facilitating increase in fighting efficiency (*i.e.* gun power, radius of action, &c.), the possibility of getting under way in a very short time, and the decrease of danger to explosives from the radiated heat of the propelling unit—have led authorities on many occasions to voice the opinion that the oil engine must be developed for higher powers. It requires only sufficient stimulus to be given for the engineer to attack with vigour whatever obstacles stand in the way of a successful issue.

The Cycle of Operation.—In considering future possibilities only the two-stroke cycle will be dealt with, as the power of the four-stroke cycle engine is limited by the difficulties of dealing with the exhaust unless auxiliary exhaust ports be introduced, in which case the reason for retaining the four-stroke cycle would seem to disappear. These auxiliary ports have been applied to a fast running four-cycle engine in order to permit of the escape of the high-temperature gases before the exhaust valve in the cylinder head opens. This method of exhaust—both with ports and a valve—will decrease the mean effective pressure of the expansion stroke, and may tend towards inefficiency of suction since at the end of that stroke these ports are again uncovered, and the quality of the suction charge may be affected. The gain in weight and space occupied with the two-cycle engine is not great, as will be explained later, especially when the extra fuel consumption, some ten per cent., is considered, but, notwithstanding this, to obtain the maximum actual mean effective pressure per revolution, the two-stroke engine will be adopted. The relative merits of the two systems will not be further discussed in the present paper, nor will the double-acting system be compared with the single-acting. Whereas the double-acting engine will no doubt be an ultimate success, its future depends entirely upon the solution of many problems affecting the single-acting engine, since there are few further difficulties with a double-acting engine, more especially when the scavenging is carried out by means of ports. On the Continent, difficulties in connection with large double-acting gas engines and also with large double-acting Diesel engines for land work (500 b.h.p. per cylinder end, *i.e.*, 1,000 b.h.p. per cylinder) would seem to have been successfully surmounted.



Speed of Revolution.—Apart from naval considerations, the speed of revolution of Diesel engines will always be relatively higher than that of steam engines, since the principle of the engine demands this to give flexibility as defined by the ratio of normal running speed to minimum running speed for a continuous period under suitable working conditions. Again, the accuracy of workmanship and the excellence of materials required by those parts subject to pressure and to temperature make it possible economically to run the oil engine at a relatively high normal speed of revolution.

Piston Speed.—The question of piston speed is not one of primary importance, and with two-stroke single-acting engines it is desirable sometimes that this speed should be such as to cause a certain inertia to permit of easy lubrication. Without this high inertia, of course, the pressure is always in the one direction upon all main bearings, as shown in Fig. 5. The stroke-bore ratio is determined by considerations of: (1) Ratio of combustion volume to cooling surface. (2) Method of scavenging adopted. (3) Limits of height of engine. (4) Type of crankshaft, whether solid-forged or built-up.

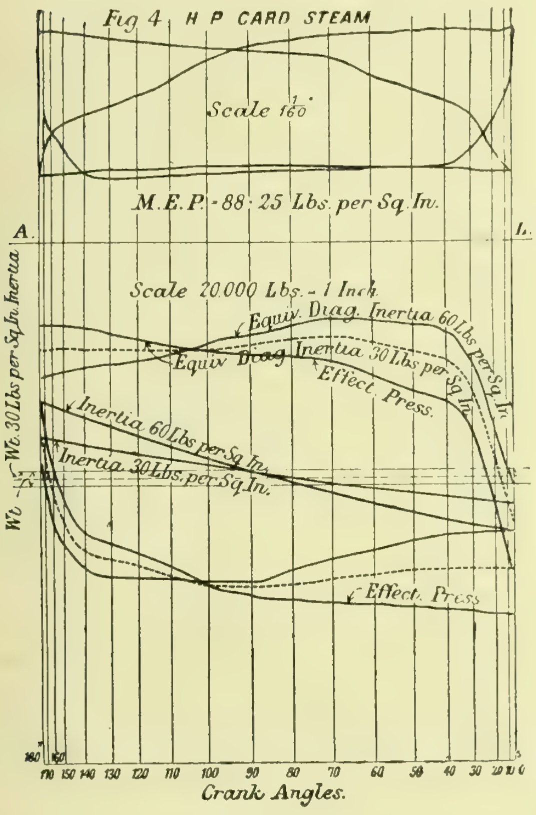


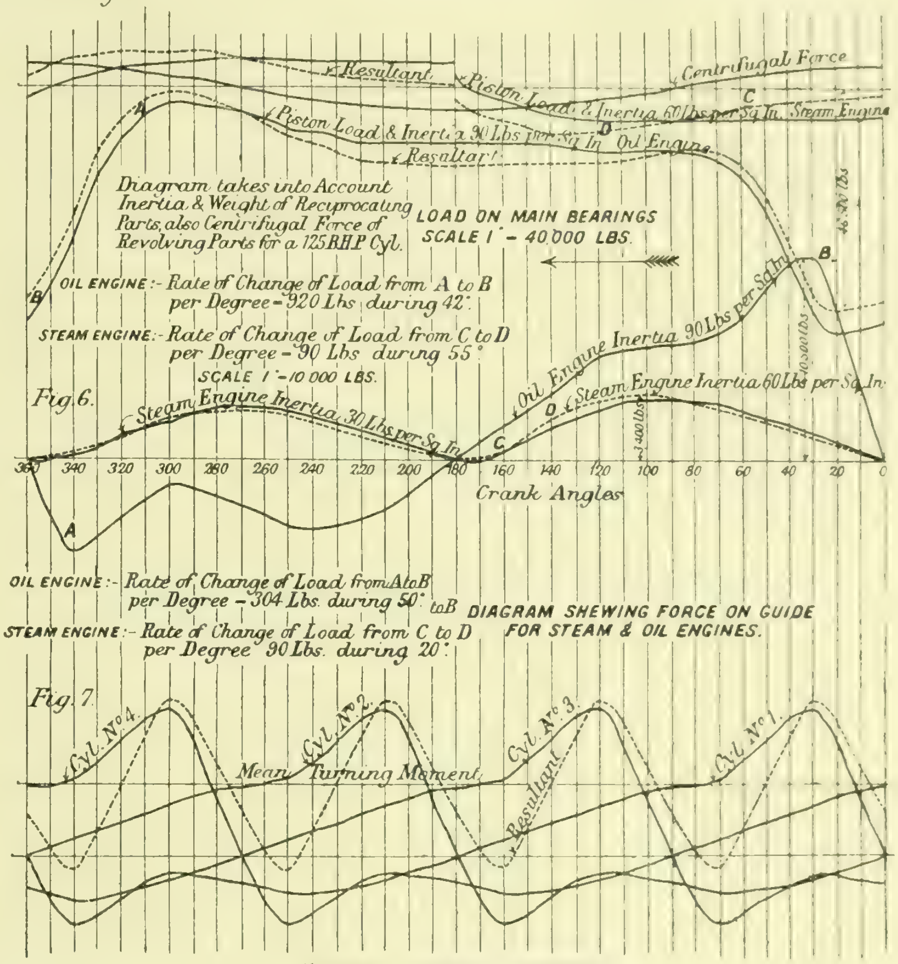
Regarding No. 2, it may be briefly stated that valve scavenging permits of a large stroke-bore ratio, whereas port scavenging requires that this be kept relatively low, so that the air introduced through the cylinder wall ports may efficiently sweep out the products of combustion in the combustion space. Compare Nos. 1, 2, 3, 6, 7, 8, and 9 with valve scavenging with Nos. 13, 14, 15, and 16 with port scavenging in Table I. For naval work, of course, the height of the engine is limited, and for a given power a small stroke-bore ratio would be necessary. To permit of a built-up crankshaft, making for a low first cost, a large stroke-bore ratio

* Paper read before the Junior Institution of Engineers, April 20th, 1914.

would be adopted. The question of the ratio of combustion volume to cooling surface should be carefully considered.

Mean Effective Pressures.—The mean effective pressure to be expected with two-cycle engines is to be seen from Table I. The pressures given are for normal running, and are seen to average some 65lbs. per square inch on a brake horsepower basis where all the auxiliaries to the engine are driven by the engine. Trial performances give higher results, and land engines can be worked at a higher output. The double-piston or Junkers type, owing to the rapid compression, also has a high mean effective pressure. The limits are those of temperature and the means by which the mean effective pressure in the future may be augmented are: (1) A higher overall efficiency of the plant, by the injection of the fuel more economically with reference to the amount of high pressure fuel injection air required. (2) Greater turbulence of the combustion air into which the fuel is injected, giving more spontaneous combustion. (3) Artificial raising of the exhaust pressure against which the engine must exhaust, so automatically raising the scavenging air pressure and all the pressures of the cycle. (4) An increase in mechanical efficiency by accomplishing more work in the cylinder at an advantageous part of the stroke, although this would inevitably be accompanied by a loss of thermal efficiency. (5) Rapid compression permitting of the minimum amount of heat to be transmitted from the air to the cooling water through the cylinder walls on the compression stroke. (6) Increase in the volumetric efficiency of the charge by means of the double-port method of scavenging, permitting the upper ports to charge the cylinder at a high pressure. (7) Introduction of high-pressure air on the expansion stroke to permit of burning more fuel and to give thus an overload.





TURNING MOMENT DIAGRAM.
SCALE 1" - 80,000 FT LBS. $\frac{\text{MAX. T.M.}}{\text{MEAN T.M.}} = 2{\cdot}15$
MAX. PRESS. 490 LBS. PER SQ. IN.

In order to accomplish Nos. (1) and (4) of the above, the author proposes the arrangement of fuel valves shown in Fig. 1. By the adoption of one or more valves, the centre valve only requires the use of highly compressed air for the injection of the fuel, and delivers fuel for sufficient power for the slowest speed desired, whilst the remaining valve or valves deliver the fuel against the lower pressure into the flame of the burning fuel delivered by the first valve. In this way the compressor capacity may be reduced, and, whilst retaining the Diesel cycle for the one valve, the main fuel is separately ignited, and thus the work is done at a later part of the stroke and more advantageous conditions as regards mechanical efficiency are established. Turbulence of the combustion air (2) is effected either by means of spiral spraying, such as is adopted with oil fuel burners for boilers, or by setting the fuel valves tangential to an imaginary circle in the combustion space. To effect the artificial raising of the exhaust pressure (3), a throttle valve in the exhaust main is all that is required. Rapid compression (5) is attained with the engines of the Junkers opposed double piston type.

Load on Engine Parts.—The cycle upon which Diesel engines work necessitates that the compression of air in the main cylinder shall generate sufficient heat for the immediate ignition of the liquid fuel as it is sprayed into the cylinder at or near the top dead centre of the engine. This compression pressure varies slightly with different sizes of engines, types of fuel, means of fuel injection, and forms of combustion space, but ranges from 430lbs. to 530lbs. per square inch, and is the cause of certain distinct phenomena which may be investigated.

The diagrams, Figs. 2 to 6, have been prepared for an oil engine and a high pressure steam engine cylinder to develop at the same revolutions—about 150 per minute—125 b.h.p. per cylinder. The indicator cards for the two engines are shown superimposed in Fig. 2. It is assumed, for the sake of comparison, that the steam engine cylinder is double-acting, and that it is the high-pressure cylinder of a triple expansion engine. Taking an average oil engine card with an inertia of 90lbs. per square inch, as shown in Fig. 3, and an average steam engine card with inertia as in Fig. 4, the diagram Fig. 5 gives the running load on the main bearings at any point throughout one complete revolution; whereas with the oil engine the maximum load is seen to be 46,500lbs. with the steam engine it is only 9,500lbs. With the oil engine the rate of change of load shown from A to B is 920lbs. per degree during 42°, whereas, with the steam engine from C to D, the maximum change is 90lbs. per degree during

55°, or, roughly, one tenth that of the oil engine throughout practically the same fraction of the revolution. With the steam engine the reversal of load is well shown. The significance of this diagram has reference to crankshafts and the general framing of the engine as well as, of course, to the question of cylinder strength, as not only must the actual amount of the load be considered, but also the rate at which that load is applied, *i.e.*, the rate of change of load which represents what is commonly known as shock. The reversal of load with the steam engine is of considerable importance when considering the question of main bearing lubrication as that reversal permits of the inflush of the lubricant. With a four-stroke oil engine, and even high speed two-cycle engines, the conditions at suitable speeds of revolution would also show a reversal due to the inertia of the reciprocating parts.

Table I.—*Particulars of Slow Running, High Power, Two-cycle Diesel Engines.*

Reference No.	B.H.P.	Revs. per Min.	Cylrs. per Eng.	Diam. in Ins.	Stroke in Ins.	Ratio Stroke / Diam.	Piston Speed ft./min.	M.E.P. on B.H.P. Basis.	Remarks.
1	1800	100	6	23·6	43·3	1·83	722	62·7	
2	1500	130	,,	20	36·2	1·80	782	67	
3	800	115	4	20	,,	1·80	695	60·5	
4	1500	150	,,	17	27	1·59	675	80·5	Trial performance.
5	1800	200	,,	17·7	22	1·25	735	82·5	,, ,,
6	750	120	,,	18·125	32·25	1·78	645	74·5	,, ,,
7	2300	130	6	17·3	31·4	1·81	680	79	No. Comp. on Main Eng.
8	3400	125	6	22·45	39·4	1·75	820	57·5	
9	2000	90	,,	24·65	47·3	1·92	710	65	
10	2000	125	3	18·9	25·6	1·35	534	73·5	Double acting. Trial performance.
11	850	120	3	,,	,,	,,	510	65	Double acting.
12	750	200	6	14·5	24	1·6	800	62·4	
13	1600	165	6	17·7	21·25	1·2	585	61	
14	1700	160	4	18·75	27	1·44	855	70·5	
15	1600	110	4	27	38	1·41	695	66	
16	4000	132	6	29·5	39·4	1·33	865	74	Land Engine.
17	1300	180	3	15·4	17·7 × 2	1·15	532	72	Double piston engine.
18	2200	150	4	17·5	20·5 × 2	1·18	513	75	,, ,,
19	800	120	3	15·75	15·75 × 2	1·0	315	72	,, ,,
20	2500	170	6	19·68	27·56	1·4	780	58	
21	1000	140	4	21·65	31·5	1·45	788	61	
22	1500	150	4	19·68	27·56	1·4	690	59	
23	500	,,	4	16·9	24	1·42	600	61·2	
24	450	200	4	11·8	16·9	1·43	564	60·2	
25	2200	130	6	24·8	35·4	1·42	540	65·5	
26	2500	150	6	20	30	1·5	750	58·5	
27	1000	,,	4	21·75	31·5	1·45	790	56·5	
28	1500	,,	4	20	30	1·5	750	52·5	
29	500	,,	,,	17·5	26	1·48	650	52·7	
30	450	200	,,	11·75	18	1·53	600	57	

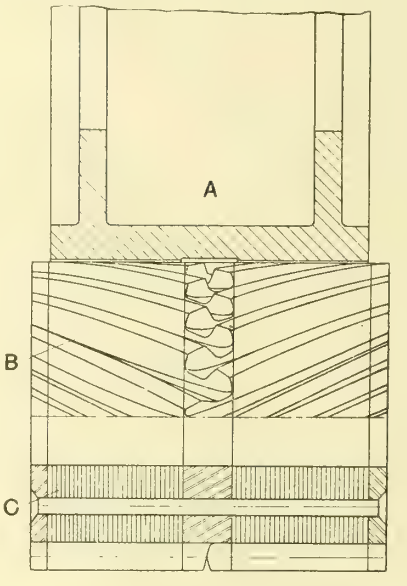
A similar diagram, Fig. 6, has been prepared to show the forces on the guide taking the same cylinders as previously, and, in this case, the total oil engine load is 10,500lbs. as compared with 3,400lbs. in the case of the steam engine. The rate of increase affecting the rigidity and materials of the framing is shown for the oil engine by the rapidly rising line A B, giving an increase per degree of 304lbs. for a total of 50° of revolution. With the steam engine, the corresponding figures are 90lbs. per degree acting throughout 20° of revolution, as shown by the line C D. With the oil engine it will be seen that in this case the load is reversed, but with the steam engine it remains constant. This means that with the oil engine the shoes of the crosshead must be very carefully designed, constructed, and adjusted, so that at the reversal of load there is no shake from the one guide to the other. With steam engines this reversal may be experienced at low revolutions, when inertia effects are negligible. If the engine be not of the crosshead type, the piston clearances must be carefully watched to obviate the piston "slogging" from one side of the cylinder to the other, and the material must be such that the wear is not excessive. In certain cases with large trunk piston engines, provision has been made for taking up side wear on the piston; but, where such is necessary, a crosshead should be provided if at all possible.

The two diagrams, Figs. 5 and 6, have particular reference to the type of framing, which, in the future, will be regarded as the standard for the high-power oil engine, as they indicate not only the large amount of the piston load and the rate at which it is applied, but also the exact proportion of that load which must be taken up by the framing through the guides and by the crankshaft. A turning-moment diagram for a four-cylinder, two-stroke oil engine is given in Fig. 7, and this shows, taken in conjunction with Fig. 3, the method of construction of this diagram for four cylinders and the ratio of maximum to mean turning moment for all the cylinders.

(To be continued.)

DOUBLE HELICAL GEARING.

In connection with double helical gearing with staggered teeth, made in accordance with the design of Mr. Caspar Wust Kunz (Patent No. 11,989, of 1902), it has hitherto been impossible to use successfully pinions made from raw hide, paper, fibre, or other compressed and intrinsically soft material, whether laminated or otherwise, owing to the displacement of such material which took place at the inner ends of the teeth where they had no support, such displacement being caused by axial pressure. To prevent such displacement of material Mr. Henry H. Thorne, Alpha Place, Yiewsley, Middlesex, proposes in a recent patent to build up the gear with a central disc of metal two outer discs of metal and between the central and each outer disc to place the compressed material, and after the whole has been securely fixed together and turned to size, to cut both the right-hand and the left-hand teeth in such a manner as to leave a metal support for the inner ends of the teeth. The metal disc is made of such width that the portion left at the inner end of each tooth after cutting supports the complete tooth profile. The mating wheel is provided with a groove in the centre of sufficient width that the wheel teeth do not come into mesh with the central metal support of the pinion teeth.



Double Helical Gearing.

Referring to the illustration, A is a portion of the double helical wheel with the groove just referred to in the middle. At B a portion of the pinion is shown in outside elevation. At C a portion of the pinion is shown in section, the compressed soft material forming the bearing portion of the teeth and the metal support in the centre being indicated by different sectioning. The pinion is shown without metal bush, but can also be made with metal bush, although this will not usually be necessary owing to the central metal disc giving additional bearing surface to the key.

Instrument for Recording Pressure Variations due to Explosions in Tubes.—At a recent meeting of the Physical Society of London Mr. J. D. Morgan described a mechanical oscillograph for recording the pressure variations which accompany a gas or other explosion in an open tube. A light steel vane of rectangular form is employed, and this is mounted parallel to the explosion tube in a cell presenting a lateral opening to the tube interior. Along three edges the vane is free, and along the fourth edge it is attached to a torsion wire. The vane is made to fit the cell as closely as possible around its edges without touching the sides of the cell. The diagram is produced by a stile on a smoked paper strip wrapped around a clock-driven drum, and on the same strip is described a time curve by an electrically-driven tuning fork of known frequency. To make the instrument dead-beat a dash-pot is mounted on the front of the vane cell and attached to the stile.

THE ELECTRIFICATION OF SWISS RAILWAYS.

IN a report lately submitted to the Administrative Council of the Swiss Federal States Railway by Chairman Dinkelmann of the railway management, and published in the "Electrical World," the substitution of electric for steam locomotives on the St. Gothard line is recommended in order to obtain higher speeds on grades, lower cost of locomotive maintenance, and the elimination of smoke from the tunnels. This report supplements and largely confirms the report of the Swiss Railway Study Commission. It is pointed out that the lack of native fuel and the abundance of waterfalls make the electrification of Swiss railways very attractive. Water-power concessions ample for electric traction had already been acquired as part of the franchise grants of the original St. Gothard Railway Company.

On account of its heavy traffic and profile conditions, the Erstfeld-Bellinzona section of the St. Gothard line is well suited for initial electrification. The cost will not be excessive and the section is ample for trial purposes. Local traffic on the Erstfeld-Bellinzona line is so small that the railway management does not recommend motor-car service until the electrification can be extended to Lucerne. Only locomotives can be considered, and most of these should be adapted for hauling any kind of train. As a general rule, passenger trains should have one locomotive, and freight trains two, one acting as pusher. These machines must be capable of exerting the present maximum drawbar pull of 22,000lbs. If desired by the connecting foreign railways, the locomotives of a through express train should be capable of exerting a maximum drawbar pull of 27,500lbs. In this event ten-car trains would be possible in place of eight. According to estimates, the traffic of 1918 would be 35 per cent., and that of 1928 70 per cent., greater than in 1911. The fluctuations in traffic throughout the year are very great. Thus in 1911 the daily minimum was 1,680,000 tons-kilogram and the maximum 2,282,000 tons-kilogram.

Generating-station sites have been chosen on opposite watersheds of the St. Gothard line, namely, Amsteg station on the north and Ritom station on the south. Fortunately, the high-water conditions for the two stations occur at different seasons. These stations would suffice for a long time for the whole of the Fifth District, in which the St. Gothard line is situated, without building a third station, which would supply enough power for many of the eastern, central, and northern lines of Switzerland.

The study commission had recommended single-phase operation at from 10,000 volts to 15,000 volts with 15 cycles, not because the single-phase system is the best for any one condition, but because it is the most flexible for Swiss railroad electrification as a whole. In commenting on this decision Mr. Dinkelmann's report takes up the three systems as follows:—

The direct-current system is the oldest and best tried, but it is universally agreed that high tensions are needed for supplying energy to heavy trains from an overhead wire. The necessary current could be obtained with a 1,000-volt third rail, but the management considered such a proposition speculative and so did not take it into serious consideration. On the other hand, a 3,000-volt direct-current overhead line would have to be very heavy to handle the loads on the St. Gothard line, nor would it be possible to use a high direct-current voltage without sacrificing some of the good weight and speed-regulating qualities of the direct-current motor. Moreover, a high-tension direct-current line would find it very difficult or practically impossible to use directly connected storage batteries.

The adoption of the single-phase system, as recommended by the commission, has been assumed in estimating the costs of the system, because it is now clear that single-phase motors of the desired output can be built, and that the single-phase locomotive has all the speed flexibility required.

The 3-phase system has certain advantages over single-phase. It is characterised by the simplicity of its traction motors, but this advantage is inseparable from very narrow speed limitations. The 3-phase locomotive is superior for certain conditions, but where there are a great many profiles the running speeds would often be too high or too low for economy. Thus the Simplon locomotives, 1906 model, are limited to the approximate speeds of 35 km. and 70 km. an hour, while the 1907 model has four speeds, namely, 26, 35, 52 and 70 km. an hour. No intermediate speeds with full tractive effort are possible. Not even a light Simplon train exceeds 70 km. an hour, and if one standard speed was raised all the others would increase also. The continuous use in 3 phase equipment of a maximum speed actually required for short periods only would in one case mean an increase of one-third in station generating equipment.

The rigid limitations of 3 phase equipment appear in another way. Thus the 1906 type of the Simplon locomotive can be coupled to those of the 1907 type only for the common speed of 35 km. and 70 km. an hour. The Giovi locomotives, which operate at 45 km. and 22·5 km. an hour, could not be worked economically with the Simplon machines. In general, the 3-phase system does not give the desired flexibility in speed. Moreover, lost time could be made up on down grades only by sacrificing regeneration, the very quality for which 3-phase is most highly praised.

If single-phase is adopted for the Erstfeld-Bellinzona line, it would be possible with little extra cost to use one potential, 15,000 volts, in some sections, and another potential, 7,500 volts, in tunnels. However, the experiences with 15,000-volt suspension in the Lötschberg tunnel will serve to settle the necessity for lower voltages in tunnels.

Despite the foregoing remarks, the management does not definitely recommend the immediate adoption of single phase, as the final decision concerning the type of propulsion equipment can be made after the hydro-electric development is fairly well advanced.

The Amsteg and Ritom stations would be fitted with 8,000 h.p., 7,500-8,000 volt single-phase generators, driven by Pelton wheels, and connected to the contact line either directly or through step-up transformers. The transmission potential would be 60,000 volts. The first feeding-in points would be at the two generating stations and at the Biasca sub station. Up to say 1918 a 7,500-volt trolley would be used and then the electromotive force could be raised to 15,000 volts with the establishment of sub-stations at Goeschenen, Lavorgo, and Bellinzona. The transmission system would be in duplicate and each line would be proportioned to carry the power needed by all lines in the Fifth District. All substations would be tied in with each other to minimise interruptions. The contact line would be of catenary type with transverse bridges on open sections. In the tunnels the overhead structure would be carried from supports fixed in the arched roof. Suitable precautions would be taken to localise mechanical failures. The rails would be bonded and depended upon for the return current.

Generally speaking, the use of the larger electric locomotives will make it possible for two such locomotives to do the work of three steam locomotives. One class of electric locomotives should be designed for a drawbar pull of 27,500lbs. and a maximum speed of 90 km. (56 miles) per hour. This type would be used primarily for through passenger service but would also be available for other operation. A second class of locomotives would be designed for miscellaneous service. Electric operation of the Erstfeld-Bellinzona section would require from 36 to 42, or even more, locomotives according to the increase in the number of trains following electrification.

One result of electrification would be faster trains. Passenger trains which now traverse the tunnel in 17 minutes would do so in 14 minutes, and freight trains would cut down their time from 30 to 23 minutes. The approximate saving is estimated at 260,000 francs a year in comparison with steam. The superiority to steam will increase with the growth of traffic and with the extensions of lines much of whose basic expenses is comprised in the present electrification. Moreover, locomotive fuel is likely to increase in cost, and the rising wage rate will affect steam more than electric operation.

In view of the foregoing statement, an appropriation of 38,500,000 francs plus 290,000 francs for amortisation of scrapped steam equipment was approved, to cover the electrification of the Erstfeld-Bellinzona line.

The Institution of Civil Engineers.—A special meeting of the Institution will be held on Tuesday, May 5th, at 9 p.m., when the 22nd "James Forrest" Lecture on "The Flying Machine from an Engineering Standpoint," will be delivered by Mr. Frederick William Lanchester, M.Inst.C.E.

APPLICATION OF ELECTRICAL DRIVING TO EXISTING ROLLING MILLS.*

BY L. ROTHERA, B.SC.

THE question of the application of electrical driving to existing rolling mills is one which is of the greatest importance to a country such as this, where, to a very large extent, steel, iron, and other metal works have been in existence for a considerable number of years, and where the question is, not the best method of putting up new works, but the best method of making an old works so economical that it can compete successfully with those in other countries, which have only within a later period entered this field, and have, consequently, been able to make use of the latest advancements of science. The subject of this paper can perhaps best be dealt with by dividing it up into two parts: (I.) The conditions which render the application of the electrical drive desirable; (II.) the method of application of the drive.

Taking first the considerations which render the application desirable, there are a number of conditions, any one of which may prove the deciding factor in the employment of electricity. Perhaps four such considerations are the most important, viz.: (1) Economy of running; (2) improved drive; (3) considerations of space; (4) greater use of existing plant. Whilst it is quite possible that any one of the above considerations may in itself prove sufficient to warrant a change-over from a steam to an electrical drive, yet it is more often a combination of the four, together with other considerations not mentioned, which make the employment of an electrical drive the only one to be considered when a change is necessary.

(1) *Economy of Running.*—Dealing first with the economy of running, that is, cost of power per ton rolled, it is, of course, not possible to make any general statement to the effect that in every case the electrical drive will prove more economical than the steam drive, as this depends entirely on local conditions, which differ to such an extent that it is only possible in a paper such as this to indicate a few of the more important ones. Instancing some of these: The first main factor is the cost of electrical energy. This cost may vary within extremely wide limits, in some cases being as low as 0·1 of a penny per Board of Trade unit, and in other cases rising up to 0·7 of a penny, or even more. The figure first mentioned,, viz., 0·1 of a penny per unit, has been, and is being, obtained under certain conditions, which represent the most economical method at present known of using available facilities. The method referred to is the employment of blastfurnace gas, coke-oven gas, or a mixture of the two, to drive gas engines for generating electric power, and using the power thus obtained for driving the steel works plant by electric motors. When it is realised that between two or three times the power is available for the gas so employed to that obtainable if the gas is burnt under boilers for the purpose of raising steam, the economy of this method is self-evident.

The cost for power between this and the upper limit will vary very widely in accordance with the method of generating power, and in steel and iron works particularly the question must often be considered as to whether a central station in the works themselves, driven either by gas, live steam raised by hand-firing, steam raised from waste heat, or exhaust steam, is not the most economical method of obtaining the necessary electric power. The charges made by supply companies vary, naturally, within wide limits, depending largely on the size of the station, cost of coal, &c., and also on the nature of the demand for power, that is, whether night or day load, and whether continuous or not, and also on the quantity of power required per annum.

The lowest figure for power in a steel works which has come to the author's knowledge is about 0·33 of a penny per unit, and the highest is in the neighbourhood of one penny per unit. It is, of course, manifest that, with the lower cost there is little, if any, advantage in putting down a central station in the works themselves to be driven by steam, unless the necessary steam is available from waste heat boilers, as, even under modern conditions of steam-turbine drive and large central station capacity, say, of 1,000 kw. upwards, it is not possible to generate at a much lower figure than 0·3 of a penny per unit, this figure covering all charges, including interest and depreciation, wages, oil, stores, &c., and no mill manager will want to be troubled with his own station when he can purchase power at practically the same cost from an outside source.

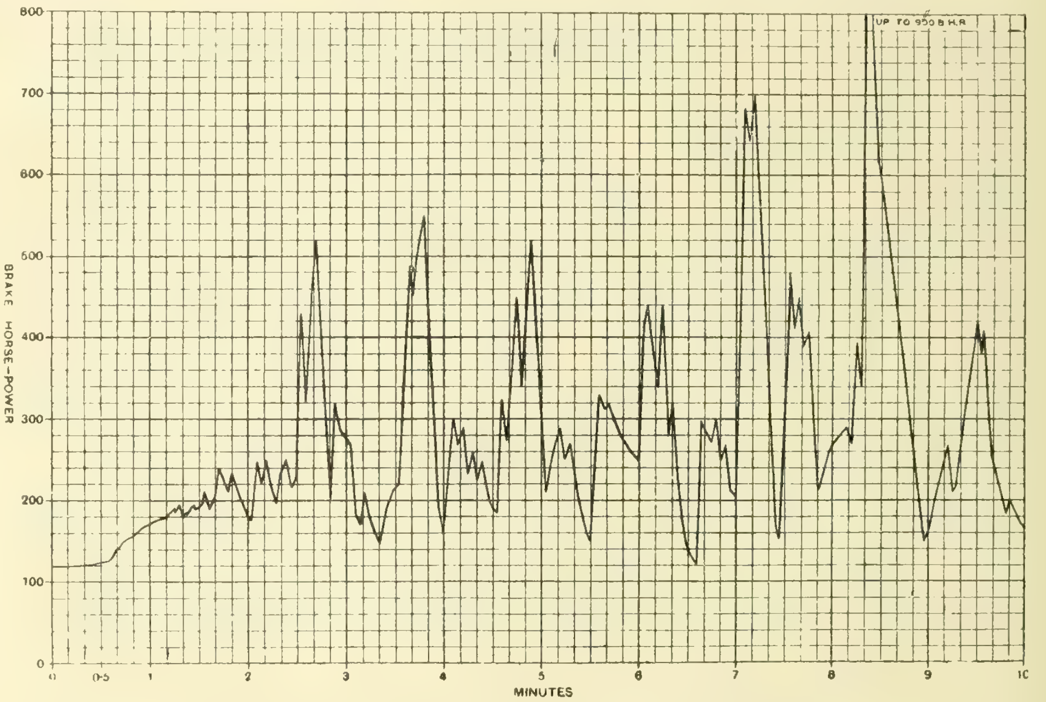


FIG. 1.—POWER DEMAND OF A SHEET MILLDRIVEN BY A 600 H.P. MOTOR.

When waste heat is available for raising steam, or exhaust steam can be employed, the conditions are quite altered, as when the coal cost, which represents usually over one-half of the total cost of power generation, can be ignored, the cost of generation is so low that any works would be well advised to install their own generating plant. The cost of driving by steam varies fairly considerably in different parts of the country, depending on the cost of coal available, cost of water, labour, and other charges, but the fact that motors have been put down, even in cases where power has to be purchased at the highest price mentioned above, goes far to prove that either the cost of driving by steam is equal to, or greater than, the cost of driving by electricity, or that some of the conditions mentioned later have proved so weighty that the electrical drive has been judged the most satisfactory one to employ.

The second factor on which the economy largely depends is the lay-out of the works. Let us consider the case of a works which originally started in a fairly small way, but which has extended very largely, and in which the boiler plant has remained centralised. The natural effect of this would be a very large number of long steam-pipe lines, all of them acting the part of condensers, and probably a number of them leaking very considerably, this condensation and

* Abstract of paper read before the Institution of Mechanical Engineers, April 24th, 1914.

leakage taking place continuously, whether the engines, which the pipe lines supply, are working or not. These conditions will, to a large extent, hold even in the case of a works where there are several boiler stations, and the quantity of coal used per year in making up for pipe line losses and wastage is a very heavy factor in the year's coal bill.

As against this wasteful condition must be taken the economical method of electric power transmission, which is carried out by small cables which can be put up anywhere quite out of the way, and in which no loss takes place when the machines, to which they convey power, are not running, and in which only a small fraction of loss takes place when the machines are running. In an old works, moreover, there will be a large number of auxiliary machines driving shears, saws, punching machines, &c., which are working under most uneconomical conditions, being nearly in every case non-condensing, and often almost indistinguishable when working, due to the steam leakage taking place round them. Contrasting the case of a small motor drive, where the efficiency is practically 88 per cent., and where power is being generated under the most economical conditions, the gain in economy is enormous, and it is now an acknowledged fact that under anything like reasonable conditions of electrical power cost the auxiliary plant in a mill is much better driven by means of electric motors.

A third factor is the class of work done. As is well known, the steam engine, whilst efficient on steady continuous load, becomes very inefficient on a widely fluctuating load. This is a condition which is not nearly so pronounced in the case of an electric motor drive, due to the fact that the efficiency over a very wide range, say, from half load up to 100 per cent. overload, varies only to the extent of 2 or 3 per cent., whilst the steam consumption of an engine may vary as much as 7 to 9 per cent. When there is a considerable length of piping in conjunction with the engine the inefficiency in the latter case is more pronounced, as continual radiation losses are taking place from the pipe line whether the engine is working or standing still. The amount of steam consumed per useful horse-power will be very materially increased through this source of loss. It may thus be generally stated that the greater the fluctuations in the load, the more advantageous the electrical drive appears. As the load on a rolling mill is, in most cases, a very variable one, varying possibly from practically no load to nearly 100 per cent. overload, the economy of the efficient electrical drive is apparent.

As an instance of this, let us take the case of a sheet mill where the average power demand, as is shown very clearly from Fig. 1, represents approximately one-third of the normal power of the motor, whilst the peak load represents practically 50 per cent. overload on the motor. This curve is an experimental one, taken on a mill driven by a 600 h.p. motor when working under normal working conditions. Assuming the maximum overload which the engine would take to be 25 per cent., the normal horse-power of the engine would have to be chosen at 720 h.p. to deal with the peak loads, so that one-third load on the motor, viz., 200 h.p., would represent only about 28 per cent. of the normal engine power. The efficiency of the motor at third load would be approximately 4 per cent. less than at full load, whilst the steam consumption of the engine would be increased at least 12 per cent., not taking into account the losses in the pipe line, which are considerable, due to the fact that the steam piping has to be designed of sufficient capacity to take the full rush of steam to meet the overload condition on the engine.

Under the question of economy must also be taken the cost of supervision of the running plant. In a large works where there are a number of engines, the running and oiling of the same becomes the task of a considerable number of men. This number can be very materially reduced where motor drives are employed, owing to the fact that, if properly designed, the motors will run for long periods without any attention whatever, and inspection once a day is all that is necessary. One electrician, to start up the plant in the morning, and to pay a periodical visit to the motors throughout the day, can deal with almost any number of machines. Contrast this with the necessity of one driver for each large engine, and a number of greasers for the small engines, and the saving to be effected per annum is very considerable.

(2) *Improved Drive.* With regard to the question of improved drive, it is an undisputed fact that a steady uniform turning moment produces a better class of rolled material than is the case with a pulsating drive. Even under the best conditions of engine practice a considerable variation in the turning moment is bound to occur, and in this respect the electric motor with its uniform constant torque is far superior. Another feature very noticeable with the motor drive is the faster working consequent on the fact that, with the even turning moment, there is not the same tendency for the roll to fail to grip the metal. Also, due to the overload capacity of the motor being in excess of that of an engine, the drop in speed whilst the metal is passing through the rolls is much less with the electric drive than with the steam drive, and in fact the amount of the drop can be regulated at will in the former case; this results in a higher average speed of rolling and consequent increased output from the mill.

Again, in rolling-mill work, one of the essentials of the drive is that of a good overload capacity. The modern electric motor will take a momentary peak load up to 100 per cent. in excess of its normal load without any risk of injury, and is thus enabled to pull a piece of metal through the rolls when an engine of the same normal power would fail to do so, with consequent delay and loss on the mill. The effect of this property of the electric motor is that, when making a comparison between the cost of an electrical, as compared with a steam drive, *it is not fair to take into account the same size*

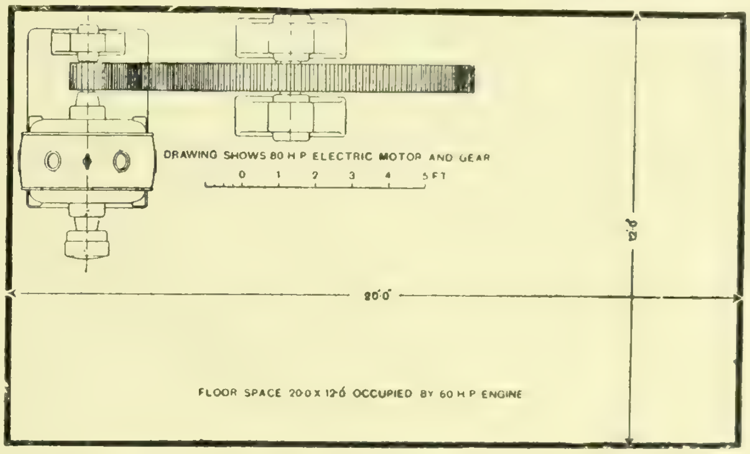


FIG. 2.
RELATIVE FLOOR SPACE TAKEN UP BY A 60 H.P. ENGINE AND AN 80 H.P. MOTOR.

of the steam engine and of motor. A larger normal horse-power of the steam engine would be necessary to give the same maximum turning moment conditions which the motor would give. The effect of this increase in the size of the engine is to raise the normal horse-power as compared with the average horse-power required, with resulting worse steam consumptions, as is clearly shown above. In addition, larger steam piping would be necessary to enable the full overload to be carried, which again would prove an increased source of loss.

Another point in favour of the electrical drive is the ease of starting and stopping the plant, so that in many cases it is found practicable when the mill is idle for short periods to shut the motor down, whereas it would not be considered in the case of a steam engine on account of the labour involved. A further feature, which is also in favour of the electrical drive, and the importance of which is perhaps only appreciated by those who are acquainted with the electrical drive, is the ease of determining for every pass the power being demanded to roll. Electrical instruments will show, with great exactitude, the demand for power at any moment, and it is possible by perhaps somewhat varying the draughting of the rolls, in accordance with these readings, to materially reduce the energy consumption per ton rolled. Such readings it is not possible to take in the case of a steam-engine drive without a great deal of trouble, with the result that serious losses may remain undetected. There is, moreover, the advantage that any increase in the power taken to drive the mill

light can be immediately detected with the electrical drive, and measures taken to remedy the defect producing such an increase.

(3) *Considerations of Space.*—This condition is, of course, of particular weight in the case of works situated in the centre of the town where it may be desired either to put down new mills, or to modify existing mills, to allow of larger operations being carried out. This condition is of such importance that, in many cases, it has been able to overcome the drawback of a heavy charge for power. When the size of a motor of moderate speed is taken and compared with the size of engine of the same power, this advantage is very clearly seen. Fig. 2 shows the floor space taken up by an engine which gives a maximum horse-power of 60, and superimposed to the same scale is shown the 80 h.p. motor, which is replacing the engine.

(4) *Increased Power.*—A case very often arises where a mill manager is anxious to enlarge the power of his driving engines, and the question then arises as to how this is to be done. In a great many cases the amount of steam available would not be sufficient to allow of the installation of larger engines without expensive alterations to boiler plant, and it is in such a case that the installation of electrical plant can show very favourably. Given below is an example based on actual figures illustrating this point. The case is one of an ironworks where a proportion of the steam used is raised from waste heat boilers over puddling furnaces, and the remainder of the steam required is raised by hand-firing. The question may arise as to how: (1) The hand-firing can be dispensed with, and (2) an increased power obtained.

Assume that the works has four rolling mills, consisting of a forge train, two merchant mills, and a sheet mill, the mills being driven by two engines, one driving the forge and one merchant mill, the other driving the sheet mill and the other merchant mill. Let us take an output of 30 tons of puddled bars from the forge train, 18 tons of flats, rounds, &c., per turn from the merchant mill attached to this engine, eight tons per turn from the sheet mill, and 12 tons of rounds from this merchant mill. In order to obtain the above output, a total quantity of coal of approximately 1,980 tons per month would be used in the furnaces, and in addition approximately 270 tons of coal under hand-fired boilers. Taking steam evaporation from the furnaces at three times the weight of coal consumed, the steam raised from the furnaces would be 13,300,000lbs. per month, and from the steam under the boilers, assuming seven times evaporation, 4,240,000lbs., that is, the total quantity of steam per hour would be 30,000lbs. The whole of this steam is at present being employed in driving the above two engines, steam hammers, and a few small auxiliary engines.

Suppose it was proposed to replace the engines by an electrical drive, the problem is to find out whether any economy would result. Under the above conditions of output it can be taken that the total number of units to roll the tonnage mentioned would be approximately 400 kw. per hour. In order to deal with this, and also the auxiliary plant, which would perhaps take 70 kw., a 500-kw. turbine would be installed. The steam pressure raised in boilers above puddling furnaces is usually very low, about 40lbs. per square inch, and under these conditions a steam consumption of approximately 20·1lbs. per kilowatt-hour would be necessary, that is, the total quantity of steam required would be 10,500lbs. per hour. The amount of steam produced from the waste heat boilers alone is 23,000lbs., and taking the steam required for the hammers at 4,000lbs. per hour, there is left available no less than sufficient steam to raise a further 400 kw., and at the same time give a saving in hand-firing of 270 tons of coal per month.

The above figures, which speak for themselves, and which are in no way exaggerated, show conclusively how under such conditions by the installation of electrical plant an extremely large saving per annum can be made, and at the same time a very largely increased power rendered available from steam already existing. An actual instance of this is the case of an ironworks where three of the main engines and all the auxiliaries were replaced by motors of very considerably increased power, and a central station was put down for supplying them. Since the electrification no fewer than eight hand-fired boilers have been permanently knocked off.

Another interesting case to consider is that of a reversing mill plant in which the roughing and finishing mills are driven from the same engine. Suppose it is desired to increase the output of the mill, a method of doing so is to divide the mill up, driving the finishing mill and roughing mill separately. Assuming that the question of capital cost renders the complete electrification of the mill impossible, then the existing engine can be retained for driving the finishing mill, and under the usual conditions of merchant mill work, the exhaust steam from the reversing mill engine will be sufficient to generate enough power to drive the roughing mill electrically. Whilst by doing this the output of the mill may be practically doubled, yet the drive will not be so economical as it would be if the whole plant was driven electrically, due to the better steam consumption of a turbine driving a generating set as compared with that of a reversing steam engine working under rolling-mill conditions, this better economy more than counter-balancing the losses due to the conversion into electrical energy.

The above conditions are, perhaps, particularly favourable for the installation of electrical drive, but there are a very large number of considerations which come into question, which must be very carefully weighed before deciding that the electrical drive will not pay, even if the actual cost of electricity consumed per ton rolled is in excess of the corresponding steam cost; for instance, the cost of maintenance on an electric motor is very much less than that of a steam engine. The cost of supervision is also very much less. The reduction in the oil consumed per annum is another item which must not be lost sight of, and in one particular case where electrical plant replaced steam drives, the reduction in the oil consumed was 80 per cent. When, in addition to the above advantages, the absence of steam pipes with their cost of upkeep, and the cleanliness of the electric drive, are remembered, there are many cases where these advantages alone outweigh, perhaps, a slightly increased capital cost, or a power consumption cost, which would appear to be more than that of a steam engine, when taking into consideration alone the *steam consumption* of the engine.

A point which should always be borne in mind is, that although an engine may be designed to be very economical indeed on full load, yet the conditions of a rolling mill are such that these conditions are practically never obtained, and the only fair method of comparing the electrical with the steam drive is to take, in the latter case, the *cost of coal per annum*, and not the steam consumption of the engine, and contrast this with the power cost of the motor.

The subject is so wide that the above instances can be multiplied indefinitely, but perhaps sufficient has been said to show that, in a vast number of cases when everything is taken into consideration, the electrical drive can more than hold its own in economy, certainty, and adaptability, and when it is considered that in the last five or six years more than 200 mills have been driven electrically in this country, such drives covering every type of mill in use, the future appears to hold out the prospect of the electrical drive displacing every other.

Before passing on to the method of applying the drive, it would perhaps be well to make a few remarks with regard to the advisability of using continuous current or 3-phase current as the source of power. This is a question which is fairly often settled by the conditions of supply prevailing in the district, but, if it is a question of generating power in the works themselves, very careful consideration must be given on account of a number of reasons. When looking into this question the following factors must be considered: (1) The most suitable type and cost of the central station plant; (2) the cost of transmitting the power to the various points where it is required; (3) the most suitable types of motors for the main drives, the most suitable types of motors for the auxiliary drives.

In the case of a works lying closely around the central station, the capital cost involved by installing a 3-phase plant or a continuous-current plant would be approximately the same, but should there be long distances to which consider-

able amounts of power have to be transmitted, then the extra cost of cable involved in the transmission of direct current power will be very much in excess of that of a high-tension 3-phase scheme, since in the former case a voltage higher than 550 volts cannot be considered. The cost of the cables is thus very frequently the deciding factor as to whether 3-phase or continuous current shall be employed throughout the works. As against this cost must be set the, perhaps, more satisfactory working of continuous-current machines for driving auxiliaries, such as live rolls, saws, or shears, but it must be pointed out that there are very many works equipped to-day with 3-phase motors for these purposes which are giving every satisfaction.

In the case of the main mill drives, the chief question in deciding the type of motor is, as to whether a variable speed is required or not. If a variable speed is required, as in the case of merchant mills, then a continuous-current motor, which can have its speed varied by means of shunt regulation of the field, is the simplest and best proposition for the purpose. If a constant speed only is required, as in the case of a sheet mill, the disadvantages of the 3-phase motor are not so great, although, even in such cases, it is very often a question as to whether the saving in efficiency by putting in the continuous-current motor does not outweigh the greater cheapness of the 3-phase motor. This saving in efficiency is due to a number of causes, which it is perhaps of interest to enter into.

Take the case of a large sheet mill which requires a motor of, say, 1,000 h.p. or 1,500 h.p., and a speed on the mill of 30 to 32 revs. per minute. With a mill of this sort a heavy flywheel of 100 to 150 tons would be necessary, running at the mill speed, in order to equalise the very heavy peak loads attendant on this class of work, and a fall in speed of at least 10 per cent. from no load to full load would be necessary, so that proper use can be made of the stored energy.

Take now the case of a 3-phase motor, it is almost impossible to build such a machine running at a speed of 32 revs. per minute, on account of the very large number of poles which would necessarily be entailed, and even if such a machine were built, the power factor would be so bad that very few power companies would permit it to be connected to their mains. It would thus be necessary to put in a higher speed motor with some form of reduction transmission between the motor and the mill.

In the case of a continuous-current motor, there is no difficulty attached to the building of a machine to run at this speed, so that in this case there is—firstly, a saving in the transmission losses, and, secondly, a saving in slip resistance losses. These latter losses occur in the case of the 3-phase motor due to the fact that the only method of reducing the speed of a plain induction motor is by inserting resistances in the rotor circuit, and the loss in these resistances is proportional to the fall in speed. To reduce the speed 10 per cent. on full-load, as is necessary to utilise beneficially the flywheel energy, a loss of 10 per cent. would occur in the resistances. On some tests which were taken on a sheet mill it was found that the average loss due to the slip resistance losses represented between 13 and 15 per cent. of the total energy consumed, and when to this loss is added the transmission loss, which may equal another 5 or 10 per cent., the advisability of installing a direct-coupled continuous-current motor to such a mill must be very carefully weighed.

This question of providing a variable speed on the drive is one which has led to the evolution of a large number of alternative methods of enabling a 3-phase motor to work at a variable speed without the serious loss in efficiency which occurs in the case of an ordinary 3-phase induction motor, which, as mentioned above, can only have its speed varied by the insertion of resistances into the rotor circuit, which method involves a loss of power proportional to the fall in speed, that is, taking the case of a motor running with a normal speed of, say, 300 revs. per minute, there will be a loss in power and efficiency of 50 per cent. if the speed is reduced to 150 revs. per minute. The method employed has usually been the addition of an auxiliary piece of apparatus which modifies the existing 3-phase motor and causes it to act more on the lines of a continuous-current shunt wound motor.

The first method that may be mentioned is the addition of a frequency changer as it is called, which consists of a small machine driven either mechanically from the main motor, or electrically through a separate small motor. This small machine is supplied with power from the slip rings of the 3-phase motor and transforms this power into the correct pressure and frequency to enable it to be returned to the line. By this means, when the speed of the induction motor is reduced, the power, which normally would be lost in slip resistances, is returned to the line, thus making a great saving in efficiency.

A second method is to have a 3 phase motor and a small auxiliary continuous-current motor coupled together, and an electrical connection between the rotor of the 3-phase motor and the commutator of the continuous-current motor taking place by means of a separate small rotary converter. In this case the power, which would normally be wasted in slip resistances, is transmitted through the rotary converter to the auxiliary continuous-current motor, which thus adds its power to the power of the main 3-phase motor.

A third method combines the rotary converter, and the auxiliary continuous-current motor, mentioned above, into 3-phase commutator motor, thus two machines only are employed instead of three.

Any one of the above methods enables a speed regulation to be obtained in practically as simple a manner as it is obtained in the case of an ordinary shunt-wound continuous-current machine, and the efficiency throughout the range of speed remains very high.

An alternative method of getting over the difficulty of the fixed speed attendant on the employment of 3-phase power is to provide step-pulleys on the motor, and to drive through ropes on to the mill. By this means a maximum of three or four speeds at most can be given efficiently, and any intermediate value has to be obtained by the insertion of rotor resistances, which, as explained above, is a wasteful method. The method of changing over from one speed to another is also cumbersome, due to the fact that the motor has to be capable of movement both axially and in a direction at right angles thereto, in order to allow the same set of ropes to be used. In order to expedite this change-over, there have been cases where small motors have been put down for moving the beds. This type of drive, although somewhat cheaper than the systems mentioned above, has a further disadvantage in that it is not possible to obtain any desired speed between the upper and the lower limit, and experience has shown that in merchant mill work the difference of a few revolutions in the speed of the mill is of very great importance indeed for satisfactory working, and that it is worth while incurring a somewhat extra capital cost to enable this condition to be obtained.

With regard to the method of application of the drive, there are four alternatives which have to be considered: (1) A direct-coupled motor; (2) a motor driving through gearing; (3) a motor driving through a belt; (4) a motor driving through ropes. Modern practice to a great extent has gone in favour of the direct-coupled drive, even for speeds as low as those required for a heavy sheet mill, viz., 32 revs. per minute. Of course, in the case of merchant mills where the speeds may vary from 100 revs. per minute upwards, the direct-coupled drive presents no difficulties, and the question of the difference in capital cost between a direct-coupled drive and a gear or rope drive has not to be so seriously considered as is the case in a very slow speed drive. In a great many cases, however, the extra additional cost of the slow speed drive is more than counterbalanced by the gain in efficiency due to the absence of any form of transmission losses between the motor and the mill. These losses are a heavy item in the yearly expenditure, as can be seen when the losses in the various forms of transmission are considered. Taking the case of gearing, it can be assumed with a fair degree of accuracy that the losses taking place in a single reduction represent about 5 per cent. *of the power which is being transmitted.* This value is perhaps excessive when taken on a gearing which has just been newly put down, but for varied conditions of working, and when the gears have become some

what worn, it is not safe to assume that any less loss than this takes place. In the case of a rope drive the percentage loss taking place in the drive alone is a somewhat moot point, some authorities giving the losses up to as much as 10 per cent., whilst others place the figure as low as 2 per cent. As, however, one of the first authorities on rope drives suggests that a figure of 5 per cent. is a good working figure, it is probably quite safe to accept this figure as being the correct amount to take into account. Special emphasis in the case of a rope drive must be laid upon the fact that the loss occurring in the ropes remains practically constant whether the ropes are running light or transmitting power, and the loss can be taken *on the normal power which the ropes are designed to transmit.* In this respect, therefore, the rope drive is not as efficient as a gear drive, although it certainly provides a very nice flexible medium between the motor and the mill. Another drawback in the case of a rope drive is the amount of space taken up, and the cost of upkeep of the ropes, which is very considerable, the life of the ropes being a very variable figure, ranging from about two years to perhaps five or more.

With regard to a belt drive, this form of transmission has not been very extensively employed in this country for this class of work, but it has been used to a somewhat greater extent on the Continent, and has been employed for powers up to 1,800 h.p. normal and 3,600 h.p. maximum, with, it is believed, very satisfactory results.

In order to show in a simple form the losses which may occur throughout the year due to transmission losses, a case is taken of a sheet mill with a normal power of 600 h.p. on the motor, and an average power taken by the mill of 200 h.p. Assuming that the mill is working for 110 hours per week, and 50 weeks to the year, the losses in the case of a gear drive would be 5 per cent. of 200 h.p., viz., 10 h.p. for 5,500 hours, whilst in the case of a rope drive the losses would be 5 per cent. of 600 h.p., viz., 30 h.p. for the same number of hours. Taking the cost of power at ½d. per unit, the loss in these two methods of drive as compared with a direct-coupled drive would be roughly £100 in the case of the gear drive, and £300 in the case of the rope drive, representing with a 10 per cent. interest on the capital outlay £1,000 and £3,000 respectively of extra plant.

Where the question of converting an existing mill has to be considered, the method of drive adopted must be dependent, to a very large extent, on the lay-out of the works, as there may be other mills, roof columns, or other reasons, which may render any one of the drives mentioned above impracticable. One of the first questions which arises when the conversion of an existing mill is contemplated is the length of time for which the mill will have to be shut down in order to make the change-over, and it is imperative in most cases that this time should be reduced to a minimum. This consideration is one which, in a number of cases, lends itself to the introduction of a rope drive, as the foundations of the motor and the motor itself can be put down without interfering with the working of the mill, and the mounting of the rope pulley for coupling to the mill is very often a matter of quite a short time, and sometimes not much more than a long week-end. In the case of a direct-coupled drive, a method of avoiding stoppage is to introduce a long intermediate spindle between the pinions and the motor, this spindle spanning the space taken up by the existing engine. The change-over in this case from the steam to the electric drive did not involve any stoppage of the mill.

It is sometimes possible to put down the motor on the side remote from the steam engine, and this was done on the second electrically-driven reversing mill which was installed. This plant has been working now for 5½ years, and no trouble whatever has been experienced through its having been found necessary to transmit the drive through the bottom spindle to the pinions. It may be said that when this plant was first put down the engine was retained in place so that it could be re-coupled to the mill in the event of anything going wrong with the electrical drive, but it has never been used since the electrical plant has been set to work. In some cases it is possible, by the introduction of another gear wheel, to put the motor in position without shutting down the plant.

When applying a motor drive to a mill, an important consideration is the weight of flywheel to be adopted, and this is a matter which can only be satisfactorily decided through experience. It is not a safe method to assume that the flywheel, as fitted to the existing engine, will be satisfactory in the case of a motor drive, since, when an engine is overloaded, it will slow down until finally it will stall. A motor, of course, does not act in the same way, but has a predetermined drop in speed from no load up to the maximum load which it can safely stand, and if this maximum load is exceeded, the circuit breaker or switch protecting the motor will operate, shutting down the plant. In the former case, that is, of the engine, the whole of the stored energy in the flywheel is available to pull the metal through the rolls in conjunction with the engine, whilst in the latter case, assuming a 20 per cent. fall in speed between no load and 100 per cent. overload, only 36 per cent. of the stored energy is available, after which the motor ceases to drive, leaving only the flywheel stored energy. This is, to some extent, counteracted by the fact that the permissible overload on the motor will be 100 per cent. in excess of the normal power, whilst in the case of an engine the overload will not be much more than 25 per cent., but it can generally be stated that the flywheel will require to be heavier in the case of the motor drive than in the case of the engine. The heavier the wheel, of course, the steadier the power demanded from the motor, but here again the question of cost is the deciding factor, and a fluctuating load will not prove harmful to a motor provided that the maximum peaks are not excessive. This is clearly shown by the success of the motors employed for reversing mill work —where they are coupled direct to the pinions and take the full power demanded by the mill.

Another question which arises if there is some form of transmission between the motor and the mill is, as to whether the flywheel be placed on the high-speed motor shaft, or be direct coupled to the slower speed mill. Modern practice in this respect has usually decided in favour of the flywheel connected to the mill, and this would appear to be the correct solution of the matter, as, in this position, the flywheel absorbs the peak loads of the mill before they come back on to the transmitting mechanism.

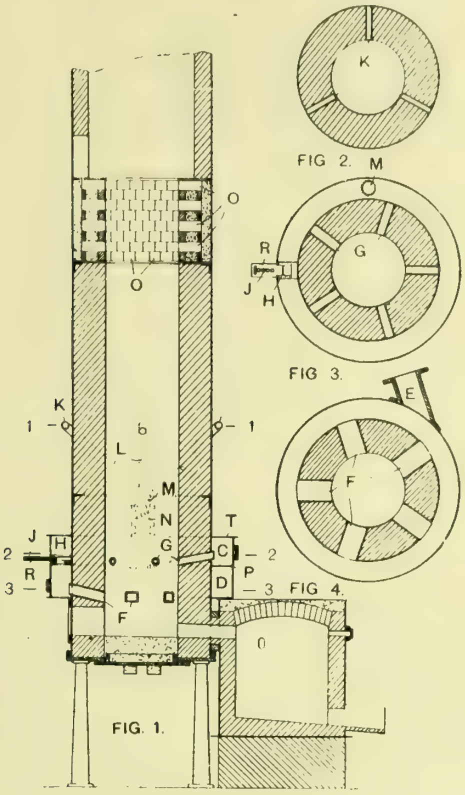
The cost of having a large slow-speed flywheel is usually somewhat in excess of having a high-speed smaller flywheel, but the difference is not, in many cases, very great on account of the fact that the full peak loads of the mill in the latter case have to be transmitted from the motor and flywheel through the gearing or ropes as the case may be. The size of the gearing, and the number of ropes, will have to be very materially increased to withstand this extra strain. As the ropes and gearing are usually admitted to be evils, the reduction of them to their smallest dimensions is advisable, and this can be done by designing them to transmit only the normal power of the motor and allowing excessive mill peaks to be taken up by the flywheel directly coupled to it.

A form of drive which has been suggested and employed in one or two cases is to mount the flywheel on the motor shaft, and to drive through a worm reduction gear on to the mill. This is a very interesting new departure, and time will show whether it possesses advantages over the better-known drives. It would appear to be a very satisfactory method if a steady power is demanded, such as, for instance, a wire mill or cold roll drive in a tinplate mill where there are no heavy peak loads to be taken up by the flywheel, but where the full power of the motor and flywheel has to be transmitted through such a gear it is to be seen whether it can be made of sufficiently strong design to give an efficient working life commensurate to the initial cost of the plant.

Institution of Civil Engineers: Awards for Papers.—The Council of the Institution of Civil Engineers have made the following awards for papers read and discussed during the session 1913-1914: A Telford gold medal to Mr. F. W. Cowie (Montreal), a George Stephenson gold medal to Mr. F. E. Wentworth-Shields (Southampton), Watt gold medals to Mr. Thos. Clarkson (Chelmsford) and Mr. Henry Fowler (Derby), and Telford premiums to Prof. E. G. Coker (London), and Mr. W. A. Scoble (London), Mr. Wm. Willox (London), and Mr. S. P. W. D'Alte Sellon (London).

A FRENCH DESIGN OF FOUNDRY CUPOLA.

THE cupola furnace shown in the accompanying illustrations, the joint invention of A. Tropenas and E. Tournier, 3, rue Bourdaloue, Paris, has for its object to utilise the whole of the heat supplied by the coke. The cupola comprises two sets of lower twyers, the auxiliary twyers arranged above the melting twyers having their blast



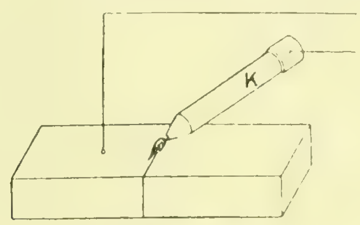
FOUNDRY CUPOLA.

box connected to the blast box of the melting twyers by means of an opening of adjustable cross-section, for the purpose of controlling the rate of flow. Fig. 1 shows the cupola in vertical section and Figs. 2 to 4 are horizontal cross-sections on lines 1—1, 2—2, and 3—3 respectively of Fig. 1. The cupola proper is provided in the usual manner with a series of melting twyers F supplied by a compressor or fan through a blast box T. The latter is divided into two compartments C D by a horizontal partition P having an orifice therein. The compartment D receives from the pipe E the whole of the air coming from the fan, and supplies the first series of twyers F. The second compartment C supplies another series of auxiliary twyers G. The air to be blown in through the latter comes from the lower compartment D of the blast box through the orifice made in the partition P, not as in known cupola furnaces, directly from the blast pipe. This orifice can be closed to a greater or less extent by means of a damper R, which slides in guide grooves secured to the partition P, and which is provided with indications corresponding to the degree of opening of the inter-communication orifice. When the damper R is completely "engaged," the air blown into the blast box T cannot pass into the upper compartment C except through small orifices J provided in the damper R so as always to keep in the twyers G of the second series a slight circulation of air preventing them from being burned. The cupola is also provided with a third series of twyers K, arranged sufficiently high to avoid producing a second melting zone. These twyers, to the number of three, are supplied through small tubes L branched on one and the same vertical pipe M. This pipe passes through the upper compartment C of the blast box T, and opens into the lower compartment D from which it is fed. The total output of the three twyers K is regulated by means of a single valve N provided in the vertical pipe M, and must be sufficient for burning the remaining carbonic oxide without introducing an excess of oxygen.

In each of the series an odd number of twyers has been arranged so as to avoid blowing exactly opposite and the consequent forcing back, the large number of twyers enabling the blast to act on the coke on a large proportion of the circumference of the shaft. The twyers have also a downward inclination of about 5° relatively to the horizontal plane, in order that the blast should reach the centre of the cupola, so as to bring about a more energetic combustion of the coke and to produce a quicker melting. By regulating the additional blast injected through the second series of twyers G, the quantity of oxygen remaining free in the products of combustion can be reduced to a minimum, and consequently the oxidation of molten metal, and the formation of fusible silicates, to the detriment of the refractory lining of the cupola, can also be reduced to a minimum. The proportion between the total cross-sectional area of the twyers and the cross-sectional area of the cupola, is determined by experience, and is such that the weight of oxygen delivered by the twyers corresponds chemically to the weight of carbon to be oxidised. Moreover, the melting twyers F which are arranged at the bottom portion of the shaft, have a rectangular cross-section, the height of which is equal to half the base, which enables the blast-penetration ring to be increased in circumference, and the height of the oxidising zone to be reduced. In the upper portion of the cupola, immediately below the mouth, the refractory lining is replaced by cast-iron blocks O capable of withstanding the blows of the pigs during charging.

A NEW ARC WELDING MACHINE.

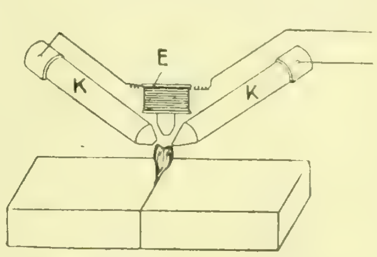
A WIDE field has been opened up to electric arc welding within the last few years. For the improvement of castings and for carrying out boiler repairs in particular, this form of welding has been extensively adopted. There are three different systems of arc welding, the oldest of which is Bernados (Fig. 1). In this system a carbon electrode is con-



K Carbon Rod

FIG. 1.—ARC WELDING PROCESS, BERNADOS SYSTEM.

nected to one pole of a source of supply, the article to be welded being connected to the other. In this manner an arc can be formed between the carbon and the work which corresponds to the flame in autogenous welding. The workman manipulates the carbon rod similarly to an autogenous welding burner; he has the advantage of only having to use one hand, however. As soon as he touches the work with the



E Electromagnet K Carbon Rod

FIG. 2.—ARC WELDING PROCESS, ZERENER SYSTEM.

carbon electrode, current passes; when he removes the electrode a few millimetres a welding arc is formed which causes the surface of the work to melt on account of its heat. If fresh metal has to be added, a bar of metal is held in the arc where it reaches a molten condition and drops on to the part to be welded. In place of the Bernados process that of Slavianoff is frequently employed. In this latter process, in place of the carbon electrode, a metal rod similar in composition to the article welded, which gradually melts, is employed. The third welding process is Zerener's, the prin

ciple of which is shown in Fig. 2. Two carbon electrodes are fixed in a suspended armature at an angle to one another. The arc formed between them is blown against the article to be welded by an electro-magnet. Both carbon rods are connected through the armature and brought over the work together, thus forming a substitute for an electric welding burner. Direct current is used in all three processes. The arc requires pressures from 45 to 65 volts. The special properties of the arc welding process make it necessary to employ special dynamos for generating the welding current. It is impossible to avoid the constant lengthening of the arc, and therefore the alteration of its resistance while welding. When the electrodes touch, for example, a short circuit is set up,

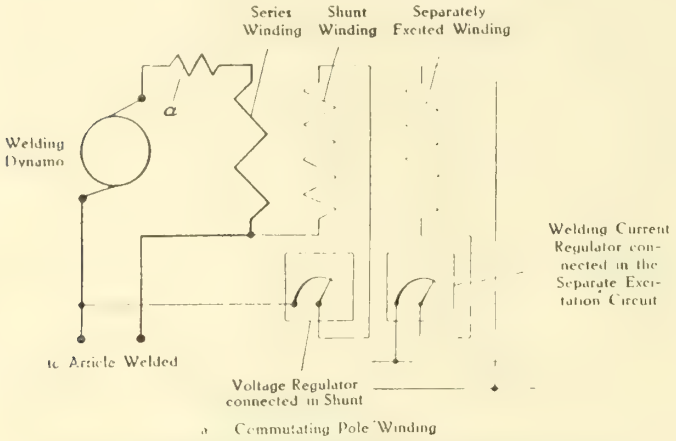


Fig. 3. Diagram of Connections for the Krämer Machine.

and on moving them backwards and forwards the length of the arc can be varied with wide limits. In consequence of the considerable changes of resistance thus brought about the current can only be taken from a direct-current network or shunt generator after special series resistances have been connected in circuit, which occasion a great loss of energy.

The A.E.G. developed methods some time ago for utilising the welding energy without losses. Further progress has now been made in this direction by the use of a welding dynamo connected in accordance with the Krämer patent. This machine generates energy at the required voltage directly, and always supplies current of the same strength

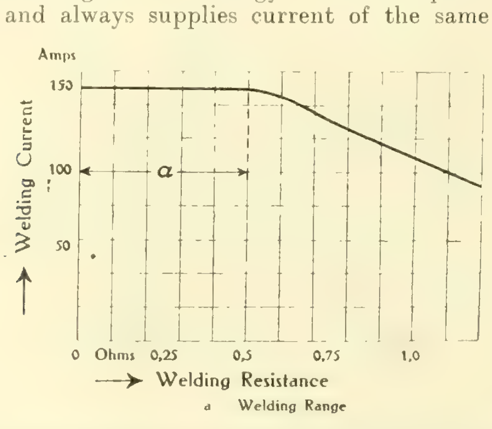


Fig. 4.—Value of the Current in Relation to the Welding Resistance.

notwithstanding considerable resistance fluctuations in the welding circuit. At the same time a perfectly steady arc is obtained. The heat flowing to the article welded is therefore quite constant, a matter of cardinal importance for satisfactory welding. The peculiar property of the new Krämer welding dynamo of giving a constant current with a variable resistance is obtained by means of a three-fold field excitation, as may be seen from the diagram of connections in Fig. 3. One field winding is a differentially connected series winding, the second is a shunt, and the third a separately excited winding which receives current from a special network with a constant voltage. Any given welding current most suitable for the work can be obtained by adjusting the regulator for the separate excitation. The voltage of the machine may be altered by the regulator for the shunt excitation. Thus a finely graduated adjustment of the current and voltage may be obtained by suitably arranging the two regulating resistances, so that the machine can be adapted within wide limits to the requirements for the welding work in hand. Fig. 4 illustrates the value of the current for a Krämer machine adjusted for a welding current of 150 amperes. It clearly shows that the welding current remains constant even when the arc resistance varies from zero (*i.e.*, short circuit) to 0·5 ohm. Only after attaining a still higher resistance does the current begin to fall gradually.—"A.E.G. Journal."

PRESENT POSITION OF DIESEL ENGINES FOR MARINE PURPOSES.*

BY J. T. MILTON.

(*Continued from page 396.*)

In obtaining the actual temperatures of the cylinder contents at any instant throughout the stroke, we know that at the completion of the suction stroke the cylinder and its clearance have been filled with air at a pressure slightly less than that of the atmosphere. The precise pressure cannot be measured with sufficient accuracy from an ordinary diagram owing to its small scale; but, through the kindness of Messrs. Burmeister & Wain, and also of the Nederlandsche Company, of Amsterdam, I have been supplied with diagrams taken with weak springs. These only show completely the exhaust and suction strokes, as, owing to the scale of pressure, the compression and impulse strokes cannot be shown on the cards, but the exhaust and suction pressures can be measured with precision. From these cards it is seen that in ordinary working conditions the pressure of the air in the cylinder at the commencement of the compression is a little less than that of the atmosphere.

We next want to know its actual temperature at that instant. There is no means of measuring this, but from the considerations given in the Appendix, which gives in detail the methods of calculation employed in the two cases taken as illustrations, a very fair approximation to the actual temperature can be arrived at. The assumption is made that the temperature at the commencement of compression is 100° Fah. From this point the ordinary laws relating to pressure, temperature, and volume of gases enable the average temperature of the gas in the cylinder to be determined at any instant, if the indicator card is a correct representation of the pressure and volume at that instant. The only special matters to remember in applying these laws to the engines of to-day are, first, that during the impulse stroke the quantity of air has been augmented beyond that shown in the compression stroke by the amount of blast air used per stroke, and, secondly, that while no change occurs in the volume of gas produced by the burning of the carbon of the fuel into CO_2, there is an increase of volume due to the combustion of the hydrogen into H_2O. The allowances for these are shown in the Appendix.

If at the point at which the pressure commences to fall the combustion were complete, and if also no heat were abstracted from the gas by the cold cylinder walls, the expansion would be adiabatic, the only loss of temperature of gas being due to the work it does during expansion. If there is a loss of heat through the cylinder walls, as of course there must be, but at the same time no combustion, the temperatures and pressures would, during expansion, fall below those due to adiabatic expansion. An examination of the two diagrams, however, will show that the actual pressure line, instead of falling below the adiabatic expansion curve, rises considerably above it in both cases. This shows that there must be so much combustion proceeding all along the stroke as to more than make up by the heat so produced for that lost by entering the cylinder walls. In the diagram of the earliest engine this takes place to such a marked extent that towards the end of the stroke the temperature is seen to be actually rising, so that the combustion here more than makes up for the waste through the cylinder walls, and also for the heat which is at the moment being converted into work.

Attention is now drawn to the marked difference in the temperatures at the latter end of stroke in the cases of these two engines. Even making very large allowances for the fact that in the earlier engine the mean pressure is so high as

* Paper read at the spring meetings of the fifty-fifth session of the Institution of Naval Architects, April 2nd, 1914.

114lbs. per square inch, whilst it is only 88lbs. in the case of the "Suecia," it will be seen that in the latter the terminal temperatures are much lower. This must have a considerable effect on the durability of the exhaust valves which are exposed to the currents of hot gases flowing over them, and which, so far, have not been artificially cooled. It may be thought, perhaps, that in the case of the "Suecia," the lower temperature is in part due to more heat being abstracted through the cylinder walls. This, however, is seen not to be the case, from the consideration, first, that the "Suecia's" cylinders are much larger than the others, consequently their cooling surface is considerably less in proportion to the volume of the gas they contain; and, secondly, from the fact that, combined with the large proportion of cooling surface in the small cylinders of the land engine, there was a very ample supply of circulating water, as is shown by the fact that this water abstracted over 20 per cent. of the total heat of combustion, this being more than half the quantity converted into work. The real cause of the comparatively low exhaust temperature is, as has been pointed out to the writer by the engine builders, the spraying of the fuel oil has been so improved that much earlier combustion has been secured.

It is recognised that the actual efficiency of a heat engine, that is, the proportion of the heat converted into work, increases by using a higher initial temperature, consequently the portion of an oil charge which becomes burnt in the early part of the stroke, where the temperature is very high, must yield up more work than an equal quantity of oil burning towards the end of the stroke, where the temperature is very much lower. Early combustion, therefore, is to be aimed at so long as it does not increase the pressure at any instant above the maximum pressure provided for in the design, and provided the temperature attained does not of itself cause troubles. A reference to the figures giving the temperatures of the gas at different points of the stroke will show that, although excellent results were obtained in the "Suecia," there is still room for further improvement, as still earlier combustion would be possible without increasing the maximum pressure.

It might be thought to be possible to further increase the thermal efficiency by carrying the expansion further. Certainly it does seem to be extremely wasteful to exhaust the gases while they are at a considerable pressure, and also while they are at a very high temperature. Attempts have been made to utilise their high temperature for steam raising, but these have not been so successful as was anticipated. With regard to the possibilities in the direction of further expansion, it must be remembered that greater expansion necessarily means larger cylinders, which will increase the loads on the mechanism in far greater proportion than the increase of work which will result. Besides this, the larger cylinders will possess larger heat-abstracting surfaces, and in view of the large proportion of the heat which is lost by the cooling water, it is easy to see that there must be a point at which any gain due to greater expansion will be accompanied by an equal loss by extra heat rejected in the cooling water. That the present practice is not far from that point is seen from the fact that the actual thermal efficiency of the engine is not much affected through a long range of power, produced by what is virtually a variation of expansion, extending from, say, 15 or 20 per cent. overload, down to about two-thirds power in many land engines, and Prof. Junkers' experiments, already quoted, show the same result.

An important point which deserves consideration is the amount of heat carried away by the cooling water. There are two distinct conditions dominating this. First, the materials of the cylinder barrel, cover, and piston must be kept sufficiently cool throughout their thickness to ensure that the temperature at no point rises so much that the strength of the material becomes unduly depreciated, and also, and this is equally important, the temperature gradient through the thickness of the metal, that is to say, the difference of the temperature of contiguous parts of the metal must not be so great that the consequent differences of expansion would cause abnormal stresses in the metal, altogether independently of the stresses due to the pressures in the cylinder.

As illustrations, take the simple cases of a plain cylindrical barrel, such as the actual cylinder liner of a Diesel engine, and of a circular furnace of a steam boiler. Both are subjected to intense heat on the inside, and both have water in contact with them on the outside. One, however, is comparatively thick and the other comparatively thin. In both cases the particles of metal forming the inner surfaces of the cylinder must be much colder than the gases in contact with them on the one side, but they must be hotter than the particles of metal next to them. Similarly the particles next the outer sides must be hotter than the water which wets them, but colder than the metallic particles adjoining them. The difference of the temperatures of the two sides of the material will depend upon the conductivity of the metal which determines the rate at which heat will flow through it. It is evident that the thicker the metal the greater will be the difference of temperature of the two sides. In a boiler furnace the material is steel, which can be relied upon as being continuous throughout the thickness, that is, it will not contain any laminations or small local defects of continuity which will impede the flow of heat through it; whilst, in cast iron, of which the cylinder liner, cover, and piston are generally made, there are always innumerable particles of graphite embedded in the metal, and these must more or less impede the flow of heat, so that with the same thickness of material and the same temperature conditions outside the two sides of it, there must always be more difference of temperature of the two sides in the case of cast iron than would exist in the case of steel plate. In a furnace in which oil fuel is burned, it is common experience that a thickness of ¾in. will withstand continuous working, if it is kept scrupulously clean on the water side, and it is generally felt that it would be unwise to exceed that thickness. In a Diesel engine the thickness of cast-iron cylinder liners, piston crowns, &c., owing to considerations of strength, must be made considerably in excess of this; in fact, thicknesses greater than 2in. have been successfully used. Now, the temperature in the furnace burning oil fuel and the maximum temperature in a Diesel engine cylinder cannot be very different. The reason the thick cast-iron metal withstands the temperature is because the latter is intermittent, not continuous. The actual temperature of the skin of the metal must depend more upon the mean of the temperature taken on a time basis than upon the maximum. This is one great argument frequently quoted in favour of the 4-cycle engine as against the 2-cycle. As will be seen from the temperature calculations given in the Appendix, the mean temperature in the former is considerably less than that in the latter, and it is quite conceivable that a much less difference might put one below and the other well above the critical temperature which would give trouble.

If now, say, in the cylinder barrel, the inner layer is raised in temperature more than the outer layer, as, of course, it must be, it will tend to expand more, and the difference in the expansion can only be accommodated by the inner layers being compressed and the outer layers being put into tension, which tension will be superimposed upon that which the liner has to bear on account of the pressure in the cylinder. It is thus quite conceivable that a thick cylinder exposed to high temperature, as well as to a high pressure inside it, will be actually more stressed than a thinner one. The same reasoning applies to the piston crown and the bottom of the cylinder covers. The metal in these parts is put into a state of compression by reason of the high temperature, besides being subject to a similar stress due to the pressure. These considerations show the great importance of keeping the thicknesses of the metal at parts exposed to great heat as thin as possible, consistent with their possessing sufficient strength. It is these considerations which lead to the impression that only comparatively small cylinders will be possible with Diesel engines.

On this point experience will be the only safe guide. Laboratory tests, although very useful, cannot reproduce the strenuous conditions incidental to constant use involving rapid variations of conditions repeated many millions of times. It, of course, does not follow that an enlargement of cylinder diameter necessarily involves a proportionate thickening of metal throughout. As an instance, it might be mentioned that in some of Messrs. Burmeister & Wain's engines larger pistons have been made with less thickness of metal than was successfully used in the "Selandia." This has been rendered possible by a modification of the design, and it is not to be supposed that no further progress can be made in this direction.

Another point which it has been thought will present difficulty is the fact that cast iron will appreciably change form and dimensions through continuous high temperatures and so

cause troubles similar to those which have occasionally been experienced in large steam engines. It was probably fear of the growth of cast iron under these severe heat conditions which led to the use of cast steel for cylinder covers. Most Diesel engine manufacturers have reverted to the use of cast iron for covers. Some of them give the metal a severe heat treatment before the completion of the machining operations. It is quite possible, however, that cast steel will be again used for these parts. There have been several cases of cracks in cast-iron cylinder covers in positions where, irrespective of the expansion by heat, the pressure on the parts puts the material into compression. In some cases these cracks have been allowed to remain, and as they have not extended when in use, it has been considered that they were due to heat stresses only. In some cases saw-cuts have been initially put into similar positions of the covers, and these cuts have prevented subsequent cracking.

From the Appendix giving the work done by each of the Diesel-engined ships it will be seen that greater troubles have, in general, been caused by the air compressors and their accessories than by the Diesel engines themselves. It must be frankly stated that this was not expected. Machines compressing air up to as great or even greater pressures than are required with Diesel engines have been in use in warships for very many years, and it was anticipated that compression would not present a difficult problem. If there have been special troubles in war vessels with air compressors, they have not become public property. Much, if not most of the trouble, has been due directly or indirectly to the lubrication with the compressors of Diesel engines. Attention was specially drawn to this point by the sad accident which occurred to the "Suecia," a Swedish vessel, on her second voyage. This vessel was built and engined by Messrs. Burmeister & Wain, and has similar engines and auxiliaries to those of the "Selandia," although they are rather smaller. When off the coast of Brazil one of her high-pressure air receivers burst. The vessel put into Rio, where the machinery was temporarily repaired, and she completed her voyage to Stockholm, where an official enquiry into the accident was held. The arrangement in this vessel is that the air used for starting as well as for fuel injection is first compressed by a 2-stage compressor, worked by an auxiliary Diesel engine, up to 20 atmospheres, and is stored at that pressure in large cylindrical receivers. The air used for fuel injection is taken from these receivers and further compressed by a high-pressure compressor worked by each main engine to 70 atmospheres, and this high-pressure air, after passing through coolers, is stored in small steel receivers, passing from them as required for injection purposes. The receivers are fitted with drains for clearing them from the water which always separates from compressed air. It had become evident during the voyage that an abnormal quantity of lubricating oil was passing through the compressor, as much oil was blown out through the drain along with the separated water. It had also been found during the voyage that the cooler pipes through which the air has to pass had on more than one occasion become partially choked with greasy matter. They had been cleared by disconnecting them, making them red hot, and so burning out the grease from them, and then blowing out the residue by means of compressed air. An examination of the damage after the accident showed that an explosion first occurred in the pipe leading from the air cooler to the high-pressure receiver, this pipe being burst in two places. The flame then passed the valve connecting the pipe to the receiver, melting a groove in it, and entered the receiver, which in its turn burst. The engine-room after the accident was filled with smoke, showing that oil combustion had occurred, and that the accident had not been due merely to over pressure caused by pumping too much air into the receiver.

When air is compressed its temperature rises, the rise of temperature becoming greater as the compression increases. In the Diesel engine cylinders, in which air compression to 35 atmospheres takes place in one stage, the temperature becomes so much raised that combustion of the oil fuel takes place immediately it is sprayed into the cylinder. In the air compressors the work is done in two or more stages, the air being cooled after each stage, so that, although the final pressure is higher than it is in the working cylinders of the engines, under proper working conditions a very high temperature is not at any time reached. It is stated that, under normal conditions, the air temperature on leaving the compressor was about 100° C. (212° Fah.), and that after passing through the cooling coil this was reduced to 40° C. (104° Fah.). When, however, the cooling coil became partially obstructed with oily deposits, a higher pressure had to be obtained in the compressor in order to force the air past the obstruction, and in these circumstances the air would occasionally attain a temperature of 300° to 400° C. (572° to 752° Fah.) before being cooled, and 60° C. (140° Fah.) after cooling. On the vessel's arrival at Stockholm when the cover to the air compressor of the starboard engine was removed, a quantity of black carbonaceous matter was found on and in the vicinity of the valve and in the air channels. In the port compressor the quantity was comparatively small and the surfaces of these parts were more oily and clean.

The explanation of the accident appears to be as follows: The lubricating oil used is a hydrocarbon oil of high flash point. The compressor passes a considerable quantity of this oil into the compressed air. Some particles become deposited upon the surfaces of the valve, valve chest, cooling spiral, and pipe connecting the cooler with the air receiver. These particles become partially dried by evaporation of their lighter constituents in the hot and dense air passing over them, the residue forming the tough and sticky composition which was found on these surfaces. When the temperature of the air is exceptionally high this sticky composition becomes carbonised, or cracked, and partially transformed into carbon. In ordinary circumstances the particles of oil which do not become deposited on the above-mentioned surfaces are carried by the air current into the receiver either as vapour or in the form of "oil fog," which, consisting of oil intimately mixed with air, form an explosive mixture. When the cooling coil becomes much obstructed, so as to cause the temperature of the air to rise considerably, as above mentioned, the deposit in the pipe becomes spontaneously ignited and the heat so generated may ignite the "oil fog" in the receiver, causing an explosion there.

It had not previously been generally realised that there was a considerable difference in the behaviour of oil in highly-compressed air from that of oil in air at ordinary atmospheric pressure at the same temperature, although it was known that it was dangerous to have oil in contact with highly-compressed oxygen. In July, 1912, a serious explosion occurred at the Electric Station at Bray, Ireland. A report, made by Mr. G. S. Taylor, H.M. Inspector of Factories, of the Home Office, has recently been published (September, 1913) giving particulars of the accident and the cause of the explosion. In this report it is stated that many explosions and failures of receivers connected with air compressing plants have been recorded in the past which have been traced to the presence of lubricating oil in the receivers, and that similar explosions have also occurred in the pipes and air vessels of Diesel engines. At Barrow, in 1911, an explosion occurred in a compressed air receiver pipe. The explosion was attributed to vapour of the lubricating oil forming an explosive mixture with the compressed air. In several other cases the explosions have occurred in the high-pressure delivery pipe near the compressor. Generally the pipes had been subjected to high temperature and contained carbonaceous deposits. It is mentioned that there is always a possibility of ignition of the oily deposits in the blast vessel by a "back fire" from the cylinder into the valve casing and blast pipe, that such a case is known to have occurred in a marine Diesel engine, in which the blast pipe was burst for a length of 20ft.

Mr. Taylor recommends that only mineral oil with a very high flash point should be used for lubricating air compressors, and that it is advisable to provide special oil separators between the compressors and blast vessels. He points out that only rarely are means provided for cleaning or examining the interior of air vessels after a period of use, and that it is considered by some engineers that the oily deposit which accumulates in the interior is an advantage, as it acts as an anti-corrosive and so preserves the metal; and he recommends that air vessels should be cleaned and examined periodically, say, at least every 12 months.

Besides the cases quoted by Mr. Taylor, the following are of interest. At one works the high-pressure air pipes are now always made of copper. They were formerly made of steel, but several accidents occurred, pieces of metal being burst out of the pipes. This was attributed to the steel pipes not possessing

sufficient ductility, and so copper is now used, and with this metal no such casualties have occurred. In the light of recent experience it is probable that the bursts were due to oil ignitions and not to faulty material of the pipes. In the case of an experimental Diesel engine an explosion of a steel high-pressure air pipe has occurred. At another works several cases have occurred of bursts in high-pressure air pipes. These always happened in the pipes conveying the hot compressed air to the cooler, none having occurred in the pipes leading from the cooler to the storage receivers. These accidents have led the firm to place the coolers close to the compressor so as to minimise the dangerous portion of pipe. In these cases copper has always been the material used for the pipes. Another firm stated that burstings have occurred, in their experience, in pipes conveying hot air from the compressor to the coolers, and that there have been quite as many accidents of this kind to pipes attached to the low-pressure and to the intermediate-pressure stages of compression as to those connected with the high-pressure stage.

An accident through combustion within an air compressor was discussed in a contribution from Mr. A. R. Ledoux, of New York, to the Transactions of the American Institution of Mining Engineers in February, 1903, and was referred to in Mr. Taylor's report. In this case the air compressor was a single stage, compressing to 80lbs. per square inch, and was being used for driving some mining machinery in one place and for ventilation in another part of the workings. There was no explosion, but the accumulated oil and carbon deposit in the delivery pipe took fire, made the pipe red hot, and the products of the combustion being delivered instead of pure air led to the death of two of the workmen. In the discussion which followed it was pointed out that the air in the cylinder at the commencement of the stroke comes from three sources, viz.: (1) The air left in the clearance space on the previous stroke; (2) that which leaks back either past the discharge valves or past the piston; and (3) the fresh air drawn in from the atmosphere. As regards (1), this is at first heated by the compression, but by expanding back to the atmospheric pressure it does work and adiabatically loses its temperature. As regards (2), however, as it expands back from the discharge pressure to the intake pressure without doing work, it maintains the temperature it had attained on discharge. The effect of this is that leakage increases the initial temperature of the charge to be compressed, and with it the temperature at which the air will be discharged at the end of the compression. A calculation is made showing that a 5 per cent. leak in the case of the compressor in use would increase the temperature by 39° and a 10 per cent. leak by 85°, and it is pointed out also that in general a leak is a constant quantity, so that when slowing down a compressor the proportionate leakage, upon which the rise of temperature depends, becomes greater. Besides the effect of leakage, either past the piston or past the valves of the compressor, there are other causes which lead to the compressed air having higher temperatures than necessary.

If the valve passages are restricted the pressure will be considerably raised in forcing the air through them. The increased pressure will be accompanied by increase of temperature, and, as in the case of the air leakage referred to, the fall of pressure when the restrictions have been passed will not cause a lessening of the temperature. Another cause has been pointed out by one of the makers of Diesel engines. The compressors are made with a greater capacity than is necessary to supply the net quantity of air required for ordinary running in order to replenish the reserves, and in some cases of twin-screw engines they are made so large that one compressor can supply the needs of both engines. Where too large a compressor is kept working, its air supply is throttled, so that only the quantity actually required is drawn into it. The wire-drawing of the supply leaves the air at the same temperature, but lessens its initial pressure, and so increases the actual ratio of compression, and with it the temperature of the highly-compressed air.

It will be seen from the foregoing what an important part of the success of a compressor lies with the lubricant. The oil itself is most probably more easily ignitable, or ignitable at a lower temperature in highly-compressed air, than it is in the ordinary atmosphere, as is known to be the case in compressed oxygen. If it decomposes under the influence of high temperatures or pressures, part of the result of the "cracking" is a lighter and more inflammable oil. It is possible that the carbonaceous deposit resulting from the decomposition of the oil is itself spontaneously ignitable in high-pressure air at not very high temperatures. If the oil decomposes and becomes sticky it will tend to clog the passages, and also to interfere with the action of the valves, making them leaky. Both these occurrences will lead to higher temperatures, and so accentuate the evil, especially in the case of separately driven compressors, which will naturally be driven faster to compensate for loss of output due to leakage. The difficulties will therefore be increasing ones. It has been suggested that sufficient lubricating oil is carried over from the first and second stages to supply all that is needed for the high-pressure stage, and that consequently there would not be much oil leave this stage to enter the receiver. It may be pointed out, however, that risk occurs at each stage of the compressions, that explosions of the connecting pipes between the stages have occurred, and that, although an explosion of a pipe would not cause so much damage as that of a receiver, yet it would equally put the engine out of action until repairs were made.

These considerations point to the importance of having the total compression performed in at least three stages with intercoolers, so as to lessen the maximum temperature obtained at either stage, and also to the importance of having the passage of the air from the compressor to the coolers as direct and short as possible, and to have these pipes and the coolers easily accessible for cleaning and clearing in the event of any deposits occurring in them. They also point to the fact that oil experts must turn their attention to the production of an oil which will stand not only high temperatures, but high temperatures in conjunction with high air pressures without either cracking, vaporising, or dispersing into oil fog.

Referring to the experience gained from the number of Diesel-engined vessels now running, both as to their reliability and their suitability for general service, it will be useful to note the action taken by shipowners who have obtained their experiences from their own vessels. The Anglo-Saxon Petroleum Company and their allies, who have now had considerable experience with the "Vulcanus" and "Juno," have no less than seven vessels now in course of construction, which will be fitted with Diesel engines. Of these, three will very shortly be running. They appear to have been cautious in not attempting large powers on one shaft, as they have adopted twin screws in vessels which, had they been fitted with steam engines, would, without question, have been single screws. The East Asiatic Company have given the greatest impulse to the movement. They started with perfect confidence by ordering the "Selandia" and two sister vessels, and they have now five vessels running, and four others in course of construction by Messrs. Burmeister & Wain, of Copenhagen. They also have arranged to take out the steam engines from three vessels of their fleet and to fit them with Diesel engines made by Messrs. Burmeister & Wain, of Glasgow. This shows the absolute confidence which the company has both in their reliability and also in their suitability for trades in which a plentiful and cheap oil fuel oil supply can be obtained. The Copenhagen firm of Burmeister & Wain have also in course of building four vessels, which will have Diesel engines, for the owners of the "Suecia" and "Pedro Christopherson." The Glasgow firm of Messrs. Burmeister & Wain, besides the engines for the three vessels mentioned, are constructing Diesel engines for six twin-screw vessels being built by Messrs. Harland & Wolff at Glasgow, and are preparing plans for a single-screw vessel, which will have eight cylinders slightly larger than those fitted in the "Fionia," which, up to the present, are the largest yet put into sea service. The running of the "Fordonian," "Rolandseck," and also of the "Monte Penedo" and "Eavestone," since the new pistons were fitted, shows that the 2-cycle engine can be made as reliable as the 4-cycle. The principal point upon which experience is now desired is as to whether the large sizes can be made as reliable as the smaller ones. The "Fionia" will be carefully watched, as hers are the largest cylinders yet afloat.

It is outside the scope of this paper to deal with the question of oil supplies. This will be a vital one, as it is only the question of all-round economy which will induce shipowners to depart from their old well-tried servant, the steam engine, and it is worthy of special notice that the East Asiatic Company, who have given the greatest impulse to marine Diesel engines, are having built at the present time three new

vessels which will be fitted with the steam machinery displaced from three other vessels by Diesel engines, the reason being that the new steamers will be employed upon a service in which coal is comparatively cheap and oil comparatively dear. When the performances of the vessels are carefully considered, allowances made for the fact that with all new introductions difficulties must occur, that some of the casualties which have occurred have been due to causes which have no connection with the Diesel-engine principle, and that the others have been remedied when they appeared, there is, in the writer's opinion, no reason to doubt that in a very short time still larger installations will be successfully made, and that the Diesel engine will be recognised as being equally reliable with the steam engine.

(To be continued.)

ROLL PRESSURE INVESTIGATION.

IN a recent issue of "The Iron Age" reference is made to some tests by Dr. J. Puppe, of Breslau, on four different three-high mills at the Peine steel plant to ascertain the roll pressures and power requirements when rolling billets, &c. The four mills, each furnished with a flywheel, had rolls the greatest diameter of which was 22·44in., 30·7in., 33·46in., and 35·43in. respectively. The three latter were driven by steam engines, and the first one with a direct-current motor. On this account satisfactory measurements regarding efficiency were only made on the first mill. Altogether the rolling pressures were obtained while rolling 101 blooms, and in the case of 46 the power used was also determined at the same time. Fig. 1 shows several characteristic pressure curves taken while rolling billets on the 22·44in. mill. In this case, as in many others, a striking thing is that the pressure on the rolls considerably increases after the beginning of the rolling, to again diminish towards the end. In all such cases it was noticed that the central part of the bars was considerably colder than the ends. The pressures reached are considerable, the highest being about 163 tons with the 22·44in. mill, about 262 tons with the 30·7in., and around 583 with the 35·43in. mill. These are pressures that thus far have scarcely been assumed, especially for mills rolling structural steel, when calculating for housings, &c. Fig. 2 shows values regarding the rolls. In all the tests it was found that often the allowable limits of stress were exceeded both with cast iron and steel rolls. At the same time it was found that the greatest stresses do not always come in the centre of the roll, but very often at other places. The results obtained along this line appear to be sufficiently exact so that calculations of the expected stresses can be made in regard to proposed rolling designs, and changes made if necessary so as to relieve the stresses in the middle of the roll.

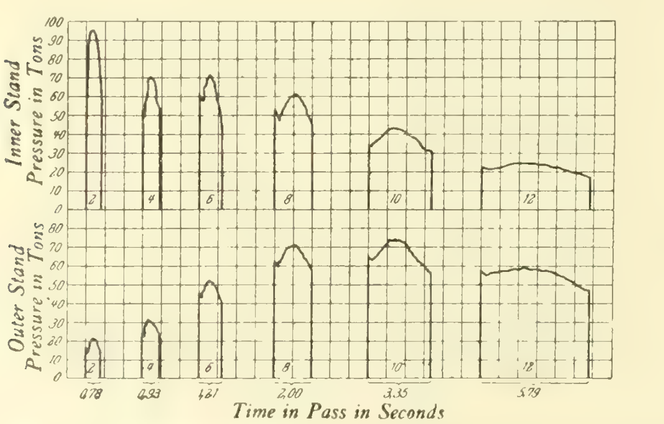


FIG. 1.—ROLL PRESSURE. TEST NO. 1. BLOOM 3. BILLETS 50 × 50MM.

Results are then given of the surface pressures on the roll bearings, which show extremely high values up to 300 kg. to 400 kg. per square centimetre. These high values cause high friction losses, the friction mostly generating heat. The amount of heat is so great that only vigorous water cooling, as used in all mills, keeps the bearings sufficiently cool. This friction causes a great loss of power, and should receive much more attention than it does at present. The various losses were calculated to percentages. The motor loss varies from 7 to 9·5 per cent., according to the load put on the motors. The loss through running idle varies from 9 to 62·9 per cent. of the total power consumed. Losses of 50 per cent. are not uncommon. The amount consumed by the bearing friction varies greatly, from about 17 to 49 per cent. The effective

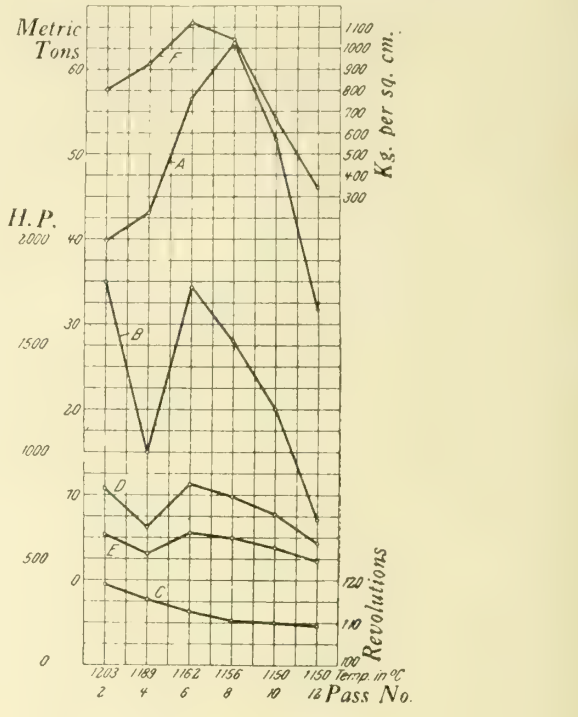


FIG. 2.—TEST 1. BLOOM 1. BILLETS 50 × 50MM.

A. Bending moment of middle roll in metric tons. B. Average efficiency, excluding running empty, in h.p. C. Average revolutions. D. Total turning movement in metric tons. E. Turning movement of upper or lower roll in metric tons. F. Calculated stress of middle roll in kg. per sq. cm.

work done is a comparatively small part of the energy used, namely, only from 27·3 to 69·8 per cent. A full account of these tests is given in "Stahl und Eisen" for January 1st and 8th, 1914.

POWER REQUIRED TO OPERATE A METAL-MIXING MACHINE.

THE results of some interesting tests made to ascertain the power required to operate a 600-ton hot metal mixer installed in the works of the Pittsburg Crucible Steel Company, appeared in a recent issue of "The Iron Trade Review." The mixer has a length of 40ft., a width of 13ft., and a height of 29ft. It is lined with firebrick 18in. in thickness and is placed on two cast-steel roller bands, which rest on 14 cast-iron rollers mounted in extra heavy cast-iron stands. The tilting mechanism is operated by means of a triple thread screw connected through gears to two reversing motors, each having a rated capacity of 150 h.p. at 470 revs. per minute. The screw is immersed in oil and is provided with a marine type thrust bearing. The motors operate on 230-volt direct current. When tilting the mixer down they are connected in series and when tilting it up are operated in parallel. The object of this arrangement is to obtain a quick return. The following table shows the power required.

Direction.	Running.		R.P.M. of Armature.	H.P.	Time. Sec.	Starting.		H.P.
	Volts.	Amps.				Volts.	Max. Amps.	
Tilting mixer down ..	228	130	310	39·7	44	225	453	137
	—	260	230	79·4	—	—	—	—
Returning mixer up ..	225	240	730	72·4	19	215	800	230

The figures indicate that 137 h.p. is necessary to start the mixer downward and 230 h.p. to start it upward. After it is in motion a maximum of 79·4 h.p. is absorbed in tilting downward and 72·4 h.p. in tilting upward. These readings were taken with the mixer empty.

THE OPERATION AND UPKEEP OF ELECTRIC MOTORS.*

BY E. F. BUTLER.

(Concluded from page 399.)

WHEN the motor runs all day and is only stopped at meal times, a plain starter with a no-voltage release will usually be sufficient. The function of a starter is to start the motor; it is not intended to be used as a switch. If the circuit is to be made or broken it should be done by means of a suitable switch which makes and breaks quickly, and preferably has auxiliary carbon contacts and a magnetic blow-out. All contacts should be renewable from the face. Except at starting no current should pass through the starter arm or spindle. The cover should be so constructed that it can be removed without interfering with the cables, and that it is not possible for the current to arc on to it.

The resistance coils should be vertical and firmly supported, and when wound on uralite or asbestos should have earthenware ends. It is an advantage to have the slate and coils mounted so that they can be lifted out together without disturbing the connections. As an alternative the case may be fitted with four removable covers.

The no-volt coil should be wound so as to release the arm before the motor is at half speed, and the iron keeper should be fitted with brass adjusting screws fór this purpose. The ends of the coil should be connected to terminals on the opposite side to the starter arm. This is necessary, as cases have occurred in which the coil ends have got trapped between the arm and the magnet and caused trouble by breaking the shunt circuit. Although the no-volt coil is usually connected in series with the shunt field, this is not always the best way. A variation in speed of 3 to 1 by means of shunt regulation is common, and at the higher speeds the field current is often too small to keep the arm up. Also to comply with the Home Office requirements it is sometimes necessary to arrange to stop the motor from several points. In such cases the no-volt coil should be connected in series with a resistance and as many push buttons as necessary, and placed across the mains. Then by pressing a button the hold-up circuit is broken and the arm flies back. When it is necessary to regulate the speed of the motor by introducing resistance in the field circuit it is important to provide an electrical interlock so that it is impossible to start the motor up on a weak field. This, especially in printing equipments, is the cause of a great deal of trouble, burning of contacts, and flashing over in motors.

One way of doing this is to use a starter with two arms. The first arm starts up the motor in the usual way, the field resistance being short-circuited until the arm is at "full on" position. In this position the other arm can be moved until the desired speed is obtained. When the current is shut off both arms drop back and the field resistance is again short-circuited. In the case of motors having to start up under a heavy load, it is often advisable to have a starter of somewhat larger capacity than the motor. If on the other hand the motor can be started up light, a starter of smaller size can be used. The greatest trouble with starters is due to getting the arm on the first contact and then moving it back to "off" position. A destructive arc is set up which burns the contacts, and often arcs to the cover. It is better to do away with the "off" position altogether, and replace the stud or segment on which the arm rests when in the "off" position by a metal one connected to the first section of the resistance. Then the motor gets current as soon as the switch is closed, and all making and breaking of current must take place on the main switch. This was done on a 70 h.p. motor working at 480 volts and taking twice full-load current at starting. After two years the contacts are as good as new, and show no signs of wear.

In a number of instances the no-volt coil gives trouble by working loose on the slate, and it is well to anticipate this by the use of either lock nuts or small spring washers. Another fitting that has the habit of working loose is the stop-block or buffer, on which the starter arm rests. Here again lock nuts or washers may prevent damage, and should the arm have a powerful spring, two buffers should be fitted so that the arm hits both of them. Automatic starters, generally speaking, require very little upkeep. The plungers should be coppered, or the solenoids lined with thin brass tube to prevent sticking. Carbon contacts should be fitted which definitely make contact before and break after the main contacts. Practically all forms of automatic starters are fitted with a resistance which is inserted in series with the lifting coil when the plunger is at the end of its stroke; most of the trouble in this type of apparatus arises from the resistance. It is well to replace such resistances with carbon filament lamps mounted in back plate holders.

To facilitate the cleaning and inspection of motors a small wall socket should be fitted whenever possible, controlled by a fuse and tumbler switch and connected to the live side of the motor switch. This can be used for an inspection lamp, and if the size of the installation warrants it, for a small power blower to remove the dust and dirt from the motor and also from the control gear. The cost is not excessive. When open-type motors have to work under bad atmospheric conditions, such as acid fumes, special precautions are necessary. The motors should be taken apart and well coated with a good-quality acid-resisting enamel—armature, field coils, frame work, brush spindles, and insulators, as much of the brush-holders as possible, and even the pigtails of the brushes. The commutator should be cleaned frequently and vaseline applied frequently while the motor is running. The starter, switch, and fuses should be treated in a like manner. Motors so treated can be worked under very bad conditions without giving trouble. The running of motors fitted with fans in dusty places can often be improved by enclosing them in a box and running sheet-iron pipes to the outside of the building.

The greatest trouble with the ordinary direct-current motor arises at the commutator or brush gear, and usually shows itself in the form of sparking. There are in all about 36 different causes of sparking. The most common of these troubles is high mica or low segments, usually termed flats. In the case of belt-driven machines about 90 per cent. of the flats are due to bad joints or unsuitable belt fasteners. Excepting in the smallest sizes all belts should be properly spliced and sewn. Other causes of flats may be looked for in flywheels out of balance, gears irregularly worn, or motors unsuitably wound for their work, such as plain shunt motors on flat-bed printing presses, punches, or planers. As a make-shift the mica can be cut slightly below the surface or recessed. Another cause of sparking is lack of tension, and is generally caused by neglecting to increase it as the brushes wear down. Sparking is also caused by brushes not fitting properly.

Some of the softer varieties of brushes swell when hot and stick in the holders. A too loose fit on the other hand will cause chattering, and in a reversing motor will cause two wearing surfaces, finally becoming rounded or wedge-shaped at the end. This will also in time wear the holder out of shape. This fault is aggravated if the holder is too far away from the commutator. The proper distance from the bottom of the holder to the face of the commutator should be from $\frac{1}{8}$in. to $\frac{3}{16}$in. One type of holder which swings from the spindle and grips the brush in a claw at the end, although not much used now, is common to a number of the older machines. If the brush wears down or falls out, as it very often does, the holder drops on to the commutator and damage is done to both. One way of preventing this is to drill a hole in the tip of the holder and fit a small peg or stop of insulating material to prevent the holder from making contact with the commutator. A better way is to scrap the holders and replace them by others of the box type; very often an old type of motor may be brought up to date and its performance improved by the substitution of a more modern type of brush gear. It is often possible by slightly modifying the holders to use up more of the brush and so reduce the cost of running. In some machines the brush has to be replaced when less than half of it has worn away.

Many machines are sent out with the oil overflow set too high, and require adjusting so that the oil comes out of the overflow instead of getting into the motor. In motors having fans or in which the armature acts as a fan, oil creeping

* Abstract of an informal paper read before the Junior Institution of Engineers, February 27th, 1914, and reproduced from the "Electrical Review."

is somewhat common and can often be cured by fitting a cap over the end of the commutator bearing, and an iron plate or piece of leather on the driving end fitting closely to the shaft. Another cause of trouble is due to the oil grooves inside the bearing extending for part of the way along the bearing and then terminating. When this is the case, a recess should be turned in each end of the bearing, the oil grooves led into it, and a small hole drilled through the grooves at the bottom of the bearing to return the oil into the well. Very often the oil grooves are too small, and can with advantage be made wider and deeper.

EFFECT OF SCALE ON BOILER WORKING.

BY K. W. BARTLETT.

Probably the greatest loss caused by the average hard water is due to the formation of scale on the heating surfaces of the boiler. Scale, being a non-conductor of heat, tends to insulate the heating surfaces of the boiler from the water within, so that to evaporate the same amount of water a greater amount of fuel must be used when the surfaces are scaled than when they are clean. As the amount of this loss depends directly upon the thickness and composition of the scale, the amount of heating surface covered, the type of boiler and the operating conditions, it is impossible to state definitely what the loss would be in any individual case. There have been a great many purely scientific experiments made, the results of which demonstrate thoroughly that an excess amount of fuel is necessary to produce results on scaled boilers. In one case of a locomotive where the heating surfaces were covered with scale ranging from $\frac{1}{32}$in. to $\frac{3}{64}$in. in thickness, it was found that the locomotive would evaporate 12·6 per cent. more water after cleaning than when the tubes were scaled, the net increase in fuel consumption in this boiler being 9·55 per cent. Another series of tests on scaled boiler tubes taken from different boilers showed that the amount of fuel required to transmit the same amount of heat through the tubes varied from 5·96 to 15·75 per cent., depending upon the thickness of scale. This fuel loss not only occurs in the boilers, but in enclosed heaters and economisers as well. In addition to the cost of this waste fuel, the cost of handling the coal and the ashes resulting from it must also be considered. In a number of cases the loss of fuel is not as important as the loss of efficiency. The insulating properties of the scale lower the efficiency of the boilers, as it is impossible to force as much heat through a scaled tube or sheet as through a clean one. This lowering of efficiency frequently reduces the actual capacity below the demand, so that additional equipment is required to carry the load. If this has to be installed there is another charge which must be placed directly against the effect of hard water. While stokers or other apparatus are sometimes installed to overcome this loss in efficiency, at the same time they have a tendency to decrease the percentage of efficiency, as the additional evaporation causes more scale to be deposited with a further reduction in the actual efficiency. The presence of scale in water-tube boilers decreases the available heating surface by building up upon the tube and decreasing the area. The general practice with scaled boilers is to put them out of service and remove the scale by mechanical cleaners, and the cost of this work, together with the investment on the tools used, must also be taken into consideration. Foaming and priming of boilers is often caused by the presence of certain scale-forming ingredients in combination with organic or suspended matter. A foaming boiler by mechanically carrying water from the boiler greatly decreases the steaming capacity, and in addition there is the danger of getting water into the engine cylinders, which tends to reduce the effect of lubrication and cut both the cylinder and the pistons. After a boiler is cleaned, the amount of fuel required to place it in service is directly chargeable against scale, as the boiler was in operating condition at service pressure when it was taken off for cleaning. The amount of coal required to accomplish this is approximately 2,000lbs. per 100 boiler horse-power, and its cost can be estimated directly by the number of B.T.U. which are required to raise the temperature of the water in the boiler from 200° Fah. to 338° Fah., which corresponds to a gauge pressure of 100lbs. As a 100 h.p. boiler holds approximately 190 cub. ft. of water, it will require 12,065,000 B.T.U. to put the boiler into service at 100lbs. pressure, which will theoretically require 1,150lbs. of coal, containing 10,500 B.T.U. per pound, or 1,533lbs. if 75 per cent. boiler efficiency is maintained. As a matter of fact, the amount of coal required will be approximately 2,000lbs. to take care of the amount of heat absorbed by the furnace and the masonry work. Scale and corrosion are responsible for a large number of boiler repairs, many of which are caused by burnt or ruptured sheets or tubes that have become overheated through the insulating effect of scale.—"The Iron Age."

PREPARATION OF PHOSPHOR-TIN.

BY THOMAS ADAMS.

Tin has a natural affinity for phosphorus and can be successfully introduced into it if the temperature of the molten tin is maintained at not over 490°. An ordinary zinc or babbitt kettle may be used for this purpose with an iron cover and iron box extending down over the bottom of the cover to act as a phosphoriser. The iron box is perforated in order that the phosphorus may enter the metal freely from the sides and base of the phosphoriser. Many accidents may be prevented by allowing the phosphorus to stand in a 5 per cent. copper sulphate solution for a period of three hours, thus causing the phosphorus to become plated with copper. A wooden box, lead lined, or some large glass receptacle may be used for this purpose. The phosphorus can then be handled without any danger; in fact it may be exposed to the atmosphere for two or three hours before it will show any sign of ignition, due to the plating of copper over the phosphorus. Another advantage of having this copper plating is that it gives the phosphorus a chance to be merged into the molten tin before expansion takes place. In making phosphorus tin use the best quality of tin to be had. By so doing you will have a higher efficiency in the manufacture of this metal. One per cent. of lead will cause a loss of phosphorus and create more than 10 per cent. of skimmings. The reason for this is, that phosphorus has no affinity for lead and acts as a scavenger. A number of firms phosphorising tin containing from 1 per cent. to 6 per cent. of lead think they show a saving, but such is not the case, however, and they are only fooling themselves. The temperature and the good quality of the tin control the success of making phosphor tin.—"The Brass World."

HINTS ON MINING ELECTRICAL PLANT.

A paper on this subject was read by Mr. J. A. Kerr before the West of Scotland branch of the Association of Mining Electrical Engineers, held in Glasgow on the 22nd ult. The author pointed out that in these days of earthing and armouring throughout it took some courage to say anything against that practice. Personally he was in favour of armouring and earthing if that could be properly carried out and maintained, but in certain cases this was impracticable. Indeed, he felt that the time and money spent in efforts to carry it out would be better utilised in making the insulation proof against the need of these devices and in providing extra copper at lower pressures. As a rule it would be much safer on small installations if earthing were not resorted to until it was found possible to get a sufficient difference of potential between each piece of apparatus and earth to cause danger. In many mines in the West of Scotland much could be said for the unarmoured unearthed system. The fact was, however, that other industries offered attractions and less onerous conditions to skilled electricians who had not had time to succumb to the fascination of mining work, with the result that men competent to keep the earthing right were hard to retain. Amongst other things, the author advocated that machines, motors, and switchgear should be standardised, thus enabling spares to be stocked and allowing repairs to be quickly carried out. At present some electrical men seemed to think that the colliery was run for the electrical installation and not vice-versâ. This attitude did an immense amount of harm, and it behoved those who were operating and maintaining plant to exercise the strictest economy consistent with safety and efficiency, not only for their own good but also for the welfare of the mining and electrical industries.

MANUFACTURE OF SMALL STEEL CASTINGS.*

BY C. S. KOCH.

The remarks in this paper are confined to castings of ⅝in. metal line and under, weighing not over 50lbs. each, and excluding so-called railroad car castings. The subject may be discussed under three different heads: (1) The production of the steel. (2) The moulding and core departments. (3) The finishing department. The processes are the converter, the crucible, and the small open-hearth (about 5 tons) furnace, excluding the electric furnace as not as yet a determining factor, and ignoring small castings made by open-hearth foundries producing large castings.

The fact that the largest number of small steel castings are made by the side-blow converter does not in itself prove that this is the best method. The best method must necessarily embrace in its advantages, not only those which make a plant run smoothly, but also those in which your customer is interested. However, neither must be given a place too far ahead of the other.

Viewing the three processes from the commercial aspect, but not from a strictly metallurgical or theoretical angle, the following comparison may be made: -

Converter Process (Side Blow).

Advantages.	Disadvantages.
1. Medium cost of steel, less than crucible, but more than open hearth.	1. Higher cost of steel than by open-hearth process.
2. Large tonnage per furnace; in fact, largest of all.	2. Operations are more complicated, or as Simonson says, "It is the best way to make the worst steel."
3. This large tonnage is of great value to a foundry, in that it can be produced during the working day, while in other processes, some metal comes to the foundry during the night turn.	3. Complicated mechanical operations, such as the unit to produce power, the blower, the tilting arrangement, any of which can suddenly give trouble.
4. Great range in carbons, especially in respect to low carbons, which are becoming a very interesting subject to engineers.	
5. Metal hotter than open-hearth and probably as hot under like conditions as crucible steel.	

Crucible Process.

Advantages.	Disadvantages.
1. Well adapted for small installations.	1. High cost of steel.
	2. Small tonnage.
	3. Variable carbons, especially the difficulty with low carbons.

Open-hearth Process, say 5-ton Furnace.

Advantages.	Disadvantages.
1. Low cost of steel.	1. Metal not as fluid, especially with low carbons.
2. Comparatively simple metallurgical operation.	2. Metal delivered to foundry usually throughout 24 hours, instead of 10 hours.
3. Not complicated in its mechanical operations.	3. Unless several furnaces are at hand, the foundry will periodically be shut down during the time required for relining.

This comparison refers to the average foundry, to operations day in and day out with ordinary skill, and omits entirely any deep theoretical considerations. My remarks are based on nothing but what has actually been observed in the trade of manufacturing small steel castings as a specialty. The comparison, which is only an outline, refers only to what has been found practical under ordinary conditions.

As to the quality of the steel produced by the various methods, I believe it can be said, without contradiction by anyone who knows, that, taking all data obtainable and forgetting all preconceived ideas, the matter of quality is not one entirely of process, but one of operators. It is not so much which process has made the record in tensile tests, &c., but what process, day in and day out, gives the best uniform results to the producers and the customers. It is my opinion that this desirable result is most often obtained by the converter, and also that the converter has the power to produce very easily low carbon steels which have been heretofore thought impossible by engineers.

It is ordinarily supposed that the phase of the steel foundry business most essential is the making of the steel; however, such is not the case. I have often found it was not one-fifth; quite recently an able producer of small castings said it was only 10 per cent. Many times a foundryman in other metals keeps away from the steel business because he thinks he knows nothing about the making of steel; usually he will find he knows less about other features.

The difference between a cupola or iron furnace and a steel furnace is not the only way in which the two trades differ. There are other features that are most essential which many fail to grasp and profit by. The moulding department in a successful plant for small castings differs greatly from that in an iron foundry and also from that in a steel foundry in large work. Some, on small work, are making moulds as if they were for large work, but their balance sheet on small work would not satisfy everyone.

The difference lies in the foreman, the equipment, the moulder, and the mental attitude of the whole organisation toward small work. Of the four, the latter is by far the most important, but perhaps the most difficult to see. The inability to realise this, however, has been the cause of many failures. Few, if any, successes have been made in small work by companies making large work, branching out into small work. These companies appeared to have every advantage—money, acquaintance, reputation—in their favour, but few have shown any great success, or their success is nothing as compared with those who were not previously on large work. The mental attitude toward work is essentially the vital difference. Tonnage must be forgotten, sales price and profit are figured so much per man, and any other way is ruinous. The differences in foremen, equipment, and moulders are more evident, but should not be lost sight of.

Only one feature of the moulding end will be discussed, the old, old question of green sand as compared with dry sand moulds. You may be interested to hear that as far as can be estimated a larger tonnage of small castings is made in green than in dry sand (there are no figures to prove this), irrespective of the use to which the castings are to be put. I am speaking of small castings machined all over, and under the severest inspection.

The points in favour of the green sand mould, referring both to the plant manufacturing them and the consumer of castings made from them are: (1) Eliminates cost of drying, both fuel and handling, especially the latter. (2) It is a more rapid system, turning out a greater product per unit of area. (3) In snap work the cores usually get only one baking. (4) In other than snap work, the flask equipment is cheaper, and is kept in much better condition. (5) Because of its yielding qualities certain designs can be made in a green sand mould not possible in a dry mould. This is in itself an advantage, but in addition to this is the fact that castings made in a green mould do not have the same strains produced, which in the final casting may remain simply as strains, or may be in the form of a crack, not visible to the eye. For this reason, if I were a purchaser of castings, I would want all intricate designs made in a yielding mould. This is a point few have grasped. They know they find green sand castings satisfactory, but do not know why they are so.

The points against are: (1) More skill is required on the part of the moulder, and this is very serious for several reasons—the moulder is higher priced; it takes longer to make a moulder, and the number of possible operatives is less. Hence in busy times it is more difficult to get up to maximum production. In other words, one is not as independent as regards labour as if dry sand moulds were being made. (2) Under equal conditions the rejections at the plant constitute a higher percentage. This is primarily due to misruns, for it is evident that a given metal will not run in a green mould as well as a dry mould. Corners of moulds will drop off, producing imperfect castings, and also the resulting sand will show up in the casting. Oversized castings may result due to strains from moulds rammed too loosely, which is a great disadvantage. The much-discussed blow-holes, due to moulds rammed too tightly, are generally considered the all-important

* Abstract of paper read before the Pittsburg Foundry Association, March 9th, 1914.

point, but, strange to say, it should not be, or better, it is not necessarily so. It is granted that without proper care more blow-holes will appear from a green mould, and hence it is placed here under the heading of a disadvantage.

I believe truly that the percentage of castings rejected and returned is no greater in the green sand foundries than in dry sand foundries. There are times when a difficult casting is given to a moulder of insufficient skill, with bad results, but this in itself does not condemn green work.

Another feature of the moulding end of small steel castings is the heading and gating. The heads and gates are excessive, and you may be interested to learn that when the percentage of good castings to total melt is 45 per cent., the practice is about normal on small work. The real essential in the moulding end is ability to rig cheaply. If moulds are made as they are in large work, the tonnage produced is so low that the cost mounts and the sales price with it.

The core department is possibly the most neglected end of the business. Except in certain malleable and grey iron foundries, the core rooms are not run with any degree of efficiency. The reason given by most managers for this state is that they have no repetition work; that is, the numbers from a given pattern do not warrant them to do any rigging or to adopt any particular system. This reason sometimes holds good in the moulding end, but it does not in the core end. After reviewing my own experience, and comparing it with others, I am of the opinion that the great majority of foundries are getting less value in the core room than elsewhere.

Core boxes are naturally divided into two classes; one in which the ramming requires the skill, the other in which the lifting of the box requires the skill. Machines for both purposes are made, and lately one has come out that will do both; that is there are jarring machines, there are drawing machines, and now those which perform both operations.

More money can be lost or saved in the moulding end and finishing room than in the furnace department in the production of small steel castings. It is very probable that the moulding end is the most important factor, but the finishing end runs a close second.

The various operations can be quickly enumerated, and it will still be hard for one to see where the difficulty lies. Heads and gates are removed in various ways, probably the greatest tonnage by cutting-off machines; followed by the simple hand cutter with a second man on a sledge, and last by saws of various kinds. The remaining operations are rumbling or sand blasting, grinding, annealing, repairing by some sort of welder, finishing, straightening in many cases, and finally inspection. In many small castings the cost per ton is greater in this department than is the cost in the moulding department.

The making of small steel castings has not been a business conspicuous by any great successes, but, on the other hand, has been marked by many failures, and had these latter been on a large scale the fact would have been impressed on the minds of all. As these failures have so frequently been by small companies, or have been only a part of some large concern, not materially affected thereby, they have been overlooked.

In the Pittsburg district within the last seven years there have been nine new companies, only two of which are in existence to-day, omitting one recently started. That means that there has been one failure each year, and only two successes in seven years. What has caused these failures, not only in the Pittsburg district, but in the country at large? This is best answered by the following summary of difficulties:—

(1) Most new plants for making small castings have used the side-blow converter. In hands unskilled and in hands too economical, this process will surely be a factor against the production of profits. (2) The moulding has been carried on as if small and large castings can be handled alike. (3) Very often too little money has been considered necessary, and in most cases what money was at hand was not properly distributed over plant, equipment, and working capital, usually too much being put into plant account. (4) No cost system worthy the name. (5) Organisations run on a scale too economical, and hence few, if any, realised the high cost of manufacture and high over-head charges, since they had no good cost system. (6) Castings sold at too low a price

The first four of these causes are more or less self-evident, but the fifth and sixth are ones which contain many points, and to which there are many ramifications.

West of Scotland Iron and Steel Institute.—The 22nd annual general meeting of this institute was held in Glasgow on the 24th ult. The president (Mr. Walter Dixon) occupied the chair. The report of the council and the treasurer's statement showed the institute to be in a flourishing condition. The meeting afterwards took up the discussion of papers by Messrs. Desch and Whyte on the "Influence of Manganese on the Corrosion of Steel," and by Mr. N. K. Turnbull on "Hot Galvanising."

Birmingham Association of Mechanical Engineers.—At a recent meeting of this Association, Mr. G. E. Storey read a paper on "Condensation." He gave a short description of the various types of condensers and air pumps at present competing for public favour. He said that the prominence which marked the position occupied by the subject of efficient condensation of exhaust steam was due to the great development of the steam turbine, and to the fact that the best results could only be obtained in the turbine by the maintenance at a reasonable expenditure of power of the very highest degree of vacuum obtainable. The outstanding feature of the present situation in relation to condensing plants was the extending adoption of various kinds of rotary and fixed water-jet air pumps in the place of the Edwards or other reciprocating air pumps, which had held the field until quite recently. Rotary pumps, however, were not entirely convincing as ousting the reciprocating air pump from its exalted position as the most economical type under practically all circumstances. The intrinsic value of rotary pumps was less than that of reciprocating pumps for equal duties, and the fact that they were offered usually at a lower price probably accounted to some extent for their present vogue. The running costs, which, rather than the capital outlay, really made for the commercial success or failure of a plant, were much lower in the case of the Edwards air pump than in that of any of the rotary water-jet pumps, though in varying degrees. What was wanted was an impartial examination by some recognised authority of the working results of all the different machines now produced to deal with the present high-vacuum conditions.

Sheffield Society of Applied Metallurgy.—At the annual general meeting of this society, held on the 24th ult., a paper by Mr. G. B. Brook and Mr. C. O. Condrup on "The Use of Fuels other than Coke for the Melting of Non-ferrous Metals," was read by Mr. Condrup. The paper dealt with experiments conducted by Messrs. Brook and Condrup. So far as they had gone, it was stated, the matter had been one of cost, the advantage being with gas. From a sulphur content point of view, oil had the advantage, whereas for general convenience of working, gas took first position. The difficulty of every manufacturer in preventing deterioration of the metal by the action of the air during the melting process, *i.e.*, oxidation, was also being investigated, and it was hoped that the results of these would be ready in the course of a few weeks. There were further features to investigate. They were desirous of assisting Sheffield trade, and, in order to carry out their programme efficiently, would be grateful for the co-operation of the manufacturers towards this end. Dr. W. E. S. Turner, senior lecturer in chemistry, was appointed president, and the other officers were elected as follows: Vice-presidents, Messrs. Ellis H. Crapper, B.Eng., W. Thorpe Haddock, Ernest A. Smith, A.R.S.M., W. G. Turner, and Cecil H. Wilson; council, Dr. E. Colver-Glanert, Dr. Greenwood, Messrs. W. R. Barclay, A. Benton, A. Bowker, Byron Carr, A. Jefferson, L. G. Reynolds, and F. C. Robinson; secretaries, Messrs. G. Bernard Brook and Frank Mason. It was reported that the council had decided that a research medal should be established, carrying with it a small grant to be bestowed on any student in the University doing such original work in non-ferrous metallurgy which should be deemed of sufficient importance by the council.

INDUSTRIAL AND TRADE NOTES.

Output of Tin in the Malay States.—The output of tin in the Federated States during the first quarter of 1914 amounted to 12,377 tons, as compared with 11,506 tons and 11,536 tons in the corresponding periods of 1913 and 1912 respectively.

New Telephones in 1913.—The Postmaster-General states that 48,448 new telephones had been provided last year in the British Isles, of which 31,000 were in London. Of provincial cities Manchester headed the list with 4,131, followed by Birmingham with 3,161, Liverpool with 3,057, and Glasgow 3,033. Applications in hand numbered 3,373, of which 1,650 were in London.

Messrs. T. W. Broadbent, Ltd., electrical manufacturers and contractors, Victoria Electrical Works, East Parade, Huddersfield, have made arrangements with Messrs. James C. Fisher and Co., of 62, Robertson Street, Glasgow, to represent them for the sale of generators, motors, &c., for both alternating and continuous current, in Scotland.

The Printing and Allied Trades Exhibition.—This Exhibition, to be opened at the Royal Agricultural Hall, by the Lord Mayor of London, on May 13th, promises to be of exceptional interest. It will be the largest and most representative Exhibition of its kind ever held in any part of the world. The Exhibition, which has the support and patronage of the various societies associated with the printing and allied trades, will remain open until May 30th.

Conciliation in Labour Disputes.—According to the President of the Board of Trade, last year there were 99 cases of trade disputes in which the assistance of the Board had been employed under the Conciliation Act of 1896. Actual stoppage of work occurred in 53 cases involving 127,900 persons. The corresponding figures for 1912 were 73 cases, 34 stoppages, and 1,110,000 persons affected. Including the corresponding figures for 1911, a total of 264 cases had been dealt with by the Board. In 144 of these work was stopped, involving in the aggregate 1,803,100 persons.

A New Submarine.—Messrs. Vickers, Ltd., Barrow-in-Furness, launched, on the 23rd ult., a submarine for the British Admiralty. The vessel is of the E class, and when fitted up will embody all that experience has taught regarding submergible construction. She will have a greater speed both under water and on the surface than previous types, and will be a much more powerful engine of attack. She will carry quick-firing fore and aft guns, which are designed to sink out of sight after discharge. She is fitted with wireless telegraphy, and will be propelled by heavy oil engines of the latest and most advanced type.

The Proposed Channel Tunnel.—Sir Francis Cox, in a brief address delivered at the House of Commons, on engineering questions connected with the construction of the Channel Tunnel, said that if one was constructed there would have to be another, and possibly a third, for motor traffic and mails. It would give a tremendous impetus to work all over the country. If there were any element of danger in it they would have nothing to do with it. A ferry across the Channel was impracticable. The estimated cost would be £16,000,000. The revenue at 10s. per head was estimated at £1,550,000 per annum, or £1,135,000 net. The tunnel would take seven years to construct.

Electric Railways of the United States.—The United States Bureau of the Census has issued some interesting statistics relating to electric railways of the continental United States. The statistics cover the years 1902 and 1912. They include electric-lighting plants operated in connection with electric railways and not separable therefrom, but do not include mixed steam and electric railroads or of railways under construction during the census year which had not begun operations. The figures show that the number of operating companies increased from 817 in 1902 to 975 in 1912, or 19 per cent. There were 41,065 miles of track in 1912, as compared with 22,577 in 1902, or an increase of 82 per cent. The gross income in 1912 amounted to 117 millions sterling, as compared with 50 millions sterling in 1902, or an increase of 134 per cent. The operating expenses amounted to 66½ millions sterling in 1912, as compared with 28½ millions sterling in 1902, or an increase of 134 per cent. The total horse-power of the power plants was 3,665,051 in 1912, as compared with 1,349,211 in 1902, or an increase of 172 per cent. The horse-power of the waterwheels increased from 49,153 in 1902 to 471,307 in 1912, or 859 per cent. The output of stations amounted to 6,052 million kw.-hours in 1912, as compared with 2,261 millions in 1902, or an increase of 168 per cent. The energy purchased in 1912 amounted to 2,967 million kw. hours, the figures for 1902 not being available.

Factory Act Prosecution.—On the 23rd ult., at South Shields, Messrs. Pyman, Bell, & Co., Ltd., were charged under the Factory and Workshops Act with having failed to cover certain electric overhead wires with insulating material or to so place and safeguard them as to prevent danger so far as was reasonably practicable. Mr. W. B. Lauder, inspector of factories, said defendants occupied a large area of ground at the west side of Tyne Dock, where they stored pitprops, and there were five circular saws driven by electricity, which were used to cut the props into suitable lengths. In order to supply the energy to the electric motors at the saw benches there were three electric overhead wires, 22ft. from the ground, and they were supported on wooden poles. On March 12th, a man named Beck, who was employed by the defendants, was engaged on the top of the stacks of pitprops, 17ft. high, and was throwing down the props to two other workmen who were loading the wagons. One of the men noticed that there was something wrong with Beck, and, on climbing to the top of the stack, he found that he had collapsed. The three electric wires had sagged down on to the top of the stack, and one of them lay across Beck's chest; another was underneath him, and he was grasping a third wire in his right hand. The current was shut off, but the man was already dead, having been electrocuted. At the time of the accident two layers of props had been removed, and that left a space of 6ft. between the top of the stack and the wires. The breach of the regulations was that the defendants had failed either to limit the height of the stacks, or to insulate the wires so as to protect the workmen from possible danger. A fine of £5 and costs was imposed.

Proposed Trade Union Alliance.—An important conference of representatives of the Executive Committees of the Miners' Federation of Great Britain, the Transport Workers' Federation, and the National Union of Railwaymen, was opened in London on the 23rd ult. It had been convened as a result of a resolution passed by the Miners' Federation at their annual meeting in favour of some steps being taken to secure closer co-operation between the three organisations, and instructing the Executive Committees to formulate a scheme to bring such decision into effect. The conference decided that a working agreement or scheme between the three bodies (representing 1,350,000 members) was desirable. After some discussion the following resolutions were agreed to: "That in the opinion of this Conference a working agreement or scheme between the three bodies represented here is desirable; that a sub-committee equally representative of the three bodies be appointed for the purpose of drawing up and submitting a scheme to a future conference for consideration; that joint secretaries be appointed and instructed to secure from all societies represented all information necessary to enable this committee to draft a scheme." The joint secretaries were appointed as follows: Messrs. T. Ashton (secretary of the Miners' Federation), J. E. Williams (secretary of the Railwaymen's Union), and Robert Williams (secretary of the Transport Workers' Federation). It was agreed that those three, with Messrs. Smillie, Bellamy, and Gosling, the respective chairmen of the miners, railwaymen, and transport workers, should form a joint committee, and that it should be left with them to call another conference immediately they were in a position to report on a scheme.

Trade Circulars and Catalogues.—We have received the following trade circulars and catalogues: From Sir Wm. H. Bailey & Co., Ltd., Albion Works, Manchester, descriptive illustrated circular relating to the "Strebor" cylinder escape valve for automatically relieving steam engine cylinders of condensed water, and so avoiding the risk of water hammer with all its attendant troubles. From the Herbert Frood Company, Ltd., Chapel-en-le-Frith, circular of test results obtained at the Physical Laboratory with "Ferodo" friction surfaces made by the Frood Company for brakes and clutch linings. From Mitchells, Ashworth, Stansfield, & Co., Ltd., Bridge End Mills, Waterfoot, near Manchester, circular relating to "Mascolite" fibre mats for engine foundations for damping the vibrations and noise trouble arising from vibration. From the Hoyt Metal Company, Ltd., 26, Billiter Street, London, E.C., a leaflet of useful hints on the lining of bearings with this well-known anti-friction metal; the hints are practical, and should be useful to those who have work of this kind to do. From J. C. Lyell & Co., Ltd., 113, Great Portland Street, London, W., descriptive circular and price list of their Oxy-Acetylene system of welding and cutting metals, giving full particulars of their acetylene generators and gas accessories. From Donovan & Co., 47, Cornwall Street, Birmingham, particulars of electric warming plates and domestic heating apparatus, as well as switches and their accessories. From Murphy Stedman & Co., 180, Grays Inn Road, London, W.C., particulars of a number of oil- and coke-fired heating furnaces for metallurgical work, including small tilting furnaces for melting brass, copper, iron, &c., hardening furnaces as well as other specialities for forging and brazing work; in addition to price lists for all kinds of foundry requisites and accessories. From the General Electric Company, Ltd., 67, Queen Victoria Street, London, E.C., particulars of the Osram axial drawn wire lamps, which have been specially designed to throw their strongest rays in the downward direction, and are specially suitable for situations where a strong light is required over a comparatively restricted area, such as over desks in offices, banks, &c., over special tools and machines in workshops, and for staircase and corridor lighting, &c.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1912.

Propulsion of vehicles by internal-combustion engines. Royston. 5588.

1913.

Liquid fuel heated tipping furnace for smelting, &c. Price. 5436.
Controlling of the starting and working of engines. Esplen. 5582.
Method of arresting the sudden descent of pit cages in case of breakage of the hauling ropes. Banks. 7861.
Speed indicating apparatus. Chadburn's (Ship) Telegraph Company, and Howie. 7994.
Machine for measuring and recording variable force. Hele-Shaw. 8149.
Carburetters for internal combustion engines. Terry & Terry. 8156.
Furnace grates of steam generators. Neil & Neil. 8223.
Apparatus for transmitting power. Pitter. 8255.
Burners for heating steam boilers. Golland. 8290.
Compression relieving devices for internal combustion engines. Bilbe. 8329.
Carburetters for internal combustion motors. Grapin & Grapin. 8333.
Tubular heat interchanging apparatus. Still, and British Still Tube Company. 8357 and 8358.
Automatic couplings for railway vehicles. Van Zyl. 8387, 8388, and 8389.
Elastic fluid pressure turbines. Belluzzo. 8493.
Starting gear for internal combustion engines. Cairns. 8527.
Roasting furnaces for ores. Gabrielli. 8635.
Steam generators. Schmidt. 8848.
Variable speed gear for motor vehicles. Davies. 8908.
Hydraulic transmission of power. Dureigne. 8975.
Pipe cutters. Johnson. 9929.
Carburetters for internal combustion engines. Grove. 10115.
Treatment of metals or alloys to render them ductile and malleable. Westinghouse Matallfaden Gluhlampenfabrik Ges. 11017.
Starting systems for internal combustion engines. Bell. 11335.
Valves and valve mechanism. Brown. 11572.
Change speed gear mechanism. Lapierre. 11621.
Gas producers. Anderson, Meikle, & Fulton. 11712.
Method of treating liquid fuel for internal-combustion engines. Heyl & Baker. 11756.
Ore concentrating tables. Luhrig Coal and Ore Dressing Appliances, Ltd., and Eves. 12574.
Liquid fuel burner. Akt. Ges. fur Selas Beleuchtung. 12808.
Method of making pipe couplings. Mark. 12938.
Furnaces. McCourt. 12952.
Apparatus for generating cooling and storing acetylene gas. Gwilt. 13226.
Hydraulic weighing machines. Hele-Shaw. 13238.
Centrifugal governors for steam, gas, and oil engines. Eastwood. 13279.
Lubricating devices for engines. Abingdon Ecco, Ltd., and Gray. 13681.
Centrifugal fans. Alldays & Onions Pneumatic Engineering Company, and Jenks. 14103.
Suction gas producer apparatus. Houston. 15367.
Devices for indicating the position of valves. Lample. 17022.
Smoke consuming devices for furnaces. Schneider. 17707.
Starting gears for internal combustion engines. Romeyn 17901.
Carburetters. Macpherson. 18050.
Piston for internal combustion engines. Jorgensen. 18471.
Tractors. Bloxam. 18674.
Steam trap for low pressure steam-heating systems. Bousfield. 18729.
Universal joints. Hermann. 19862.
Frictional gearing. Sokal. 20256.
Internal combustion engines. Busse. 20401.
Hydraulic jacks. Law. 20930.
Rotary fans. Dick. 21777.
Forging machines. Mellersh Jackson. 22615.
Means for softening water. Buchner. 22647.
Oil engines. Mohr. 24031.
Internal combustion engines. Southall. 25094.
Process and apparatus for purifying water. Maschinen- and Waggonbau Fabriks Akt. Ges. in Simmering, vormals H. D Schmid and Von Suess. 25715.
Liquid fuel injection apparatus for internal combustion engines. Junkers. 25821.
Machines for treating compound rails. Noll. 25832.
Rolling mill and similar installations. Webster. 26112.
Connecting rod bearings. Bugatti. 27047.
Steam boilers. Patching. 27267.
Forced draught boiler installations. Hume, and James Howden and Co. 27419.
Gas producers. Dodd. 29381.
Water-tube boilers. Stirling Boiler Company, and Constantine. 29537.

1914.

Flexible metallic tubing. Rudolph. 548.
Admission valves for oil engines. Henderson. 2613.
Cylinders for internal combustion engines. Scotts' Shipbuilding and Engineering Company, and Richardson. 3266.

ELECTRICAL, 1913.

Continuous current electric hoisting apparatus. Allgemeine Elektricitats Ges. 5529.
Machine telephone switching systems. Western Electric Company. 5653.
Method of increasing the strength of magnets. May. 7898.
Incandescent electric lamps. Beckwith. 8123.
Electricity meters. Compagnie Internationale D'Electricite Soc. Anon. 11825.
Thermo electric current consumption regulator. Caminati. 17917.
Electrical resistances. Hay & Sullivan. 21109.
Electric condensers. Bloxam. 28823.
Sparking plugs. Spada. 29059.
Electric writing telegraphs. Widegren & Widegren. 29212.
Electrical switches. Lundberg, Lundberg, Lundberg, and Pegg. 29721.

1914.

Machine telephone switching systems. Western Electric Company. 895.
Transformers for use in connection with electric measuring instruments. Siemens Brothers Dynamo Works, Ltd. 2492.
Machine telephone switching systems. Western Electric Company. Ltd. 5510.
Vapour electric devices. Weintraub. 6353.

METAL QUOTATIONS.

TUESDAY, APRIL 28TH.

Aluminium ingot	86/– per cwt.
,, wire, according to sizes, &c. ......from	112/– ,,
,, sheets ,, ,, ... ,,	112/– ,,
Antimony £27/10/–	to £29/–/– per ton.
Brass, rolled	7¼d. per lb.
,, tubes (brazed)	9⅝d. ,,
,, ,, (solid drawn)	8d. ,,
,, ,, wire	7⅜d. ,,
Copper, Standard	£63/10/– per ton.
Iron, Cleveland	51/– ,,
,, Scotch	57/– ,,
Lead, English	£19/5/– ,,
,, Foreign (soft)	£19/–/– ,,
Mica (in original cases), small	6d. to 3/– per lb.
,, ,, ,, medium	3/6 to 6/– ,,
,, ,, ,, large	7/6 to 11/– ,,
Quicksilver	£7/–/– per bottle.
Silver	27¼d. per oz.
Spelter	£21/12/6 per ton.
Tin, block	£156/15/– ,,
Tin plates, I.C.	12/10½ per box.
Zinc sheets (Silesian)	£24/15/– per ton.
,, (Stettin ; Vieille Montagne)	£25/2/6 ,,

Junior Institution of Engineers: North-western Section.—A meeting of this section was held in the Municipal School of Technology, Manchester, on Friday, the 24th ult., at which a lecture entitled "Some Notes on the Application of Chain Gearing" was given by Mr. H. T. Hildage, M.I.C.E., Wh.Exh. The lecturer dealt with the present limitations of chain driving, and instanced the great progress which had been made in the subject in a very short time, and foreshadowed still further improvement and an extension of the possible achievements of "chains." The many and varied uses of chains were amply illustrated by a number of lantern views; these were accompanied by details from the author of the economies effected in power, floor space, upkeep, and first cost, of the improvement in quality of product, and of increased output.

The Mechanical Engineer. An Illustrated Weekly Journal. Vol. 33, No. 850

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Telegrams: "Scientific," Manchester.
Telephone No. 6655 City.

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Failures of Thick Boiler Shell Plates.

ALTHOUGH we cannot recall the occurrence during a great many years of an explosion of a boiler shell from the sudden development of a latent defect in the plates, the possibility of such a disaster is ever present to engineers responsible for the safe construction and working of steam boilers. This is particularly the case with boilers on board ship, where they are often of large size and worked at high pressures, and where an explosion might easily entail the loss of the ship and all on board. It is conceivable that some of the mysterious disappearances of ships at sea have been brought about in this way, for such an explosion would leave little trace behind. The possibility of such occurrences has some base for support in the fact that many failures of heavy boiler plates have been recorded after the material has passed the examinations and tests applied by Lloyd's and the Board of Trade. These failures have fortunately been discovered later during hydraulic test after completion of manufacture, but the fact that discovery should have been evaded during the testing of the material creates a fear that other defects may have escaped detection, and by passing into service have become a potential source of danger. Particulars of a number of cases of defects revealed during hydraulic test were given by Mr. Milton, the chief engineer surveyor to Lloyd's Register, in a paper to the Institute of Naval Architects in 1905,* and at the meeting of the Iron and Steel Institute during the present week the subject has again been brought under notice in a paper by Mr. S. A. Houghton, one of the engineer surveyors to the Board of Trade. Though the sudden development of fractures of the kind recorded are not unknown in land boiler practice, the phenomena are not so accentuated as they are in marine practice, where, owing to the large diameters and high pressures, boiler shell plates are

* See "The Mechanical Engineer," July 22nd and 29th, 1905, Vol. XVI., pages 110 and 173.

of much greater thickness. In the cases revealed by Mr. Milton, careful investigation of the fractures themselves, coupled with subsequent tests, suggested the existence of abnormal stresses or abnormal chemical composition which evidently escaped the usual tensile, elongation, and bending tests applied by inspecting authorities to the material at the steel works, and that in a certain percentage of cases material of apparently sound quality could become possessed of such abnormal properties as to be dangerous for use in boiler shells, even though made by the acid process, for basic steel has always, in this country at all events, been largely suspect for boiler purposes, though extensively used abroad. The question as to how the cases referred to by Mr. Milton arose, and the best methods to employ for their detection were not greatly illuminated by the discussion which took place when his paper was read, though the need of further investigation was obvious.

Mr. Houghton in his paper does carry the enquiry into the matter a little further, though it does not furnish a final solution, and, in fact, is put forward rather to elicit criticisms and suggestions than to formulate any dogmatic conclusion. The list of 21 failures recorded as coming under his notice during the last 15 years is certainly evidence that present methods are not satisfactory. These failures are divided into three classes: (1) Plates in which partial cracks only have occurred; (2) plates which have cracked right across in the boiler shop; and (3) plates which have failed under hydraulic test. We do not propose to discuss the various failures in class (1), since it is our intention to reproduce the paper in full. We think, however, they afford a good deal of support to Mr. Houghton's conclusion—that the "hammer-dressing" to which plates after rolling are often subject, to remove visible surface defects, is one of the chief causes of failure, and that this obnoxious practice should cease. Another contributory cause suggested for this class of defect is that severe internal stresses are occasionally set up in heavy plates owing to their stiffness and inability to buckle in the manner that thin plates do when the rolls are not true. That stresses may be produced in this way is undoubted, and it is equally true that it is impossible, after the plates are rolled, to determine their magnitude. A third source of trouble, it is pointed out, is the uneven cooling that arises when plates are not carefully piled after rolling, as occurs in some works, and which may lead to a plate not wholly covered being maintained for some time at a temperature of 700° C. This is well known to be dangerous owing to the molecular change brought about by the pearlite partially changing into cementite. A fourth is the practice sometimes indulged in of finishing the plates at too high a temperature, or cooling them too slowly at an improper temperature. The only satisfactory way to ensure freedom from these troubles is to anneal the plates after manufacture, but here again it would seem the ground is not clear and that pitfalls may exist, for the most suitable temperature for annealing plates has not been definitely settled, nor does it appear that one temperature is best for all, while plates containing a higher percentage of phosphorus call for more drastic annealing than those containing a smaller percentage, and, finally, it would appear that plates may be exposed to annealing temperature too long.

A good deal of Mr. Houghton's reasoning is based on the light afforded by micrographic analysis, and though to many engineers this latter-day method seems to savour too much of the laboratory to be of value in the workshop, there is no doubt it throws a flood of light on many phenomena that have hitherto been obscure, but which obviously play a large part in steel failures in practice. The micrographs show that many of the failures are due to segregation arising out of the practice of using too large a proportion of the ingot, and, conversely, to cut too small a portion away where segregation occurs. If the weight of a plate much exceeds 45 per cent. of the ingot there is a probability of a segregated portion being included in the plate, and that if the proportion of the ingot used amounts to 60 per cent. the probability becomes almost a certainty. The practice of using too small an ingot may be put down as one of the main sources of the defects recorded. It is difficult, after a defective plate has been discovered, to trace exactly how much of the ingot was rejected when the plate was rolled, but where circumstances have permitted of this being done it is clearly proved that the use of too small an ingot is not only a serious, but a rather prevalent, evil.

It is impossible here to summarise all the important features of Mr. Houghton's paper, but we cannot dismiss it without mentioning some other factors which doubtless aggravate any inherent stresses in the plate. Some of these arise from the fact that when a boiler is put to work and subject to internal pressure and temperature the movements of the structure are not uniform. As an illustration he quotes the case of the double-ended marine boiler, where at mid-length the shell plates are braced horizontally by the screwed stays uniting the wing combustion chambers to the boiler sides, so that under the influence of pressure the tendency is to elongate the vertical diameter. In addition to this a certain amount of barrelling of the shell takes place, owing to the ends being immovably fixed to the end plates. Such changes of form inevitably entail complex stresses in the shell plates, and their magnitude is difficult to estimate precisely, though it requires little consideration to show they must be serious. A number of the fractures recorded have arisen in the neighbourhood of manholes. It is obvious that where an opening is cut in a circular shell extra stresses are set up, and it is usually assumed that granted a sufficient area of section of compensating ring is afforded the local weakness due to cutting of the opening may be atoned for. It is not, however, so fully recognised that unless care is taken in riveting the compensating ring or mouthpiece, further stresses may be brought into play by the operation of riveting, especially with the powerful hydraulic machines now used. With thick plates it is difficult to make the curvature of ring and shell identical, and, unless they are so, a process of creeping takes place, which, if not carefully distributed by rimering the holes, may lead to localisation of stress at one or two rivet holes, sufficient, in conjunction with initial defects in the material or even without this predisposition, to cause fracture. Mr. Houghton summarises the results of his enquiry in the following recommendations for eliminating defects in thick boiler plates: (1) That the weight of the plate as cut should not exceed 45 per cent. of the ingot; (2) that thick plates should be effectively annealed, and a careful pyrometer and time record kept of the process; (3) that the phosphorus content should not exceed 0·05 per cent. or with arsenic 0·06 per cent.; (4) that all surface defects which require dressing should be first examined by an independent inspector and such defects afterwards stamped on the dressed part; (5) that occasional transverse tests should be taken from the centres of the ends or sides of the plates as well as from the opposite corners. It may be that the adoption of these recommendations would not entirely eliminate the obscure failures to which attention is drawn, for the causes which lead to them are complex, but they would at all events diminish the risk of their occurrence.

DECARBURISATION DURING THE HARDENING OF STEEL DIES.

In a short note read at the recent meeting of the Iron and Steel Institute, Mr. H. C. Greenwood, D.Sc., drew attention to a curious case of decarburisation during the hardening of steel dies. He stated that in some preliminary trials of an electric muffle for hardening steel dies, the steel (containing about 1 per cent. of carbon and 1 per cent. of chromium) was allowed to soak at 820° C. for an unnecessarily long time, namely, about one and a half hours, in order to make quite sure of uniformity of temperature. The working face of the die was protected against scaling by a sheet-iron cover filled with powdered charcoal. On removal from the furnace the cover was knocked off, the face brushed free from charcoal, and the block quenched under a spray. Curiously enough the working face which had been in contact with charcoal during the heating was found to be superficially soft, while all the other parts of the die (which by the way had a less sudden cooling) were perfectly hard. The surface could be filed to a depth of about half a millimetre, below which the steel was glass hard. This behaviour was not confined to a single instance, but was observed in all cases where the surface was protected in this way. If the face were left bare the surface was perfectly hard but somewhat pitted by oxidation. This difficulty was, however, overcome by using some inert powder, such as fine sand, instead of charcoal, to cover the surface, no diminution of the hardness being effected.

It only remained to seek an explanation of the paradoxical action of the charcoal in softening the surface layer. Some test strips of the steel were accordingly taken and heated under the same conditions, packed in charcoal, for about one and a half hours, while similar strips, unprotected in any way, were heated alongside. All were quenched together, and, after annealing at 600° and cleaning with emery, the respective surfaces were planed off (taking a very light cut) and combustions made of the planings. This procedure was repeated, changing round the specimens after machining off $\frac{1}{8}$in. from each surface. The analyses gave the following results: —

	First Experiment.	Second Experiment.
	Carbon, per cent.	Carbon, per cent.
Specimens protected by charcoal ..	0·38	0·59
Specimens unprotected by charcoal .	1·08	0·87

It is clear from these results that a decarburisation of the surfaces in contact with carbon had been effected, and this is confirmed by the fact that the soft skin persists on rehardening. Why such an action should take place is, however, not very obvious, and the main reason for publishing this note is to ascertain if any similar effects have been observed by others. The analytical part of these experiments was carried out in the Metallurgical Department of the University of Sheffield.

The Junior Institution of Engineers.—This Institution announce the following engagements for the present month: May 8th, Bohemian concert at Pillar Hall, Victoria Station, 8 p.m., the President, Sir Boverton Redwood, Bart., D.Sc., in the chair. May 15th, at 39, Victoria Street, 8 p.m., lecturette by Mr. W. V. Treeby on "A Few Notes on the Design of Surface Condensing Plant." May 16th, visit to Southwark Bridge widening works, 2-30 p.m. North-western Section, ramble round Buxton. May 18th, meeting at the Institution of Electrical Engineers, Victoria Embankment, 8 p.m.; paper on "Static Transformers: Their Design and Application" by F. R. Peters (Durham Bursar, 1912-13). May 21st, North-western Section, meeting at Java Café, 26, Corporation Street, Manchester, 7-45 p.m., paper on "Pattern Making" by T. R. Schofield. May 22nd, at 39, Victoria Street, 8 p.m., discussion on "The Neglected Steam Car" led by Mr. R. S. Box, M.A. May 28th, visit to Messrs. J. A. Curle, Ltd., Perseverance Glass Works, 2-30 p.m. May 29th, last Friday evening gathering at 39, Victoria Street, for present session.

RECORDING PYROMETERS.

At a meeting of the Faraday Society held on April 22nd, Mr. Charles R. Darling read a paper on "Recording Pyrometers," in connection with which a full display of the most recent types of instruments was exhibited. After referring to the pioneer work of Le Chatelier and Roberts-Austen in connection with high temperature records, the author referred to the types of pyrometer at present in use, which were capable of yielding continuous records, and dealt with the special applications of each class. The requirements of modern furnace practice in relation to records were next dealt with, a distinction being made between instruments suitable for laboratory and workshop respectively. Typical thermoelectric recorders were then described, the essential features in all cases being (1) the intermittent contact of the pointer of the indicator with the moving chart, which, in conjunction with an inking device, produced a mark indicating the temperature; (2) an arrangement consisting of an automatic switch which enabled records from several pyrometers to be secured on the same paper. The special advantages of the Siemens-Halske, Leskole, Foster, Thread, Paul, and Leeds-Northrup recorders were described by reference to the actual apparatus. It was pointed out that any of these recorders could be used in conjunction with radiation pyrometers, the chart being specially divided for such purpose. Recorders for resistance pyrometers were next described, the advantage of this type being superior sensitiveness. The examples chosen for description were the forms due to Callendar, Paul, and Northrup. It was pointed out that as in the latest patterns of recorders considerable power was available, controlled by the pyrometer, it was highly probable that the automatic control of furnace temperatures would be realised in the near future, the mechanism being utilised to regulate the supply of gas, oil, electric current, or coal dust when continuously fed. In conclusion, a tribute was paid to the National Physical Laboratory for the excellent work performed in standardising recorders and pyrometers generally, so that all types could now be relied upon to agree in their indications.

In the discussion which followed, Dr. J. A. Harker referred to the usefulness of the paper in view of the scarcity of literature on the subject, and he praised the excellence of the instruments exhibited. He hoped some information would be forthcoming with regard to the comparative life and efficacy of the various types. Some confusion in pyrometric measurements had sometimes arisen on account of the two systems of standardisation in use, namely, the usual method of comparison by reference to the melting points of certain metals, and by reference to one fixed point, namely, the melting point of potassium sulphate. This was often assumed, following the older workers, to be 1,015° C., whereas it was actually about 1,070°. Mr. R. S. Whipple thought the difficulty of working the Callendar instrument had been overrated; over 400 of these were in use in charge of men not specially skilled. Much work had been done with recorders in the control of heat supply. He instanced a steel works in which by the regulation of the hot air mains a constant temperature of 700° C. was maintained to within 10°. A spectroscope used for measuring the velocities of stars in the line of sight was being kept at a temperature constant within $\frac{1}{100}$°C. He further instanced a large soldering iron used for tinplate, where constancy of temperature was most important, which was being regulated by recorder control. Mr. C. E. Foster dwelt on the necessity of educating the user to want control. He emphasized the advantages of base metal thermocouples which gave large and constant electromotive forces. Mr. E. H. Rayner hoped the author would add to his paper a table of standard melting points, so that users of pyrometers could know what temperatures for standardising were recommended. Mr. R. W. Paul, referring to the motor drive, for which he disclaimed originality, said that it was necessary to have ample power so as to have a large margin to waste in governing. Surprising accuracy of speed was then attainable.

Mr. Darling, in replying to the discussion, said the Callendar instrument was admirable where there was no vibration. He agreed as to the future of base metal couples, as homogeneous alloys could now be obtained, but above 1,200° C. radiation pyrometers should be used.

HIGH-POWER DIESEL ENGINES: THEIR DEVELOPMENT FOR MARINE SERVICE.*

BY JAMES RICHARDSON, B.SC., A.M.INST.C.E.

(*Continued from page 406.*)

Engine Framing.—The engine framing takes the tension load due to the piston load and also the side thrust of the crosshead, and must be designed also to give to the engine the requisite degree of stiffness. In considering the latter, the question of balance of the engine must be taken into

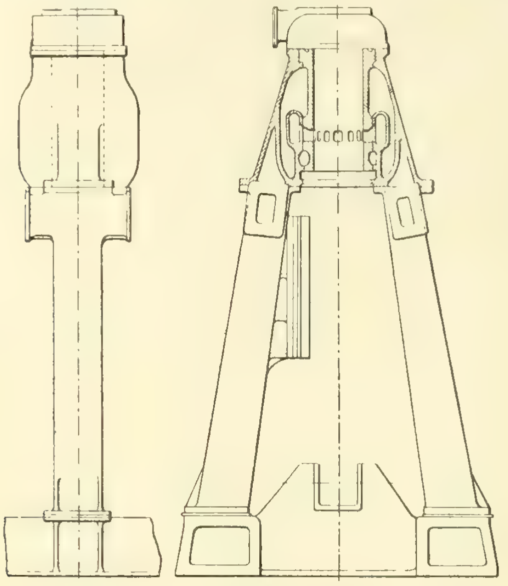


FIG. 8.

account. The following leading types of framing are suggestive of the lines upon which the high-power engine will be developed: (1) The mercantile steam-engine framing of cast-iron columns at the back and the front of the engine (Figs. 9 and 10). A combination of cast-iron columns with turned-steel columns at the front, frequently adopted with steam engines, is shown in Fig. 11. (2) The cylinders supported on a cast-iron framework for rigidity, whilst the piston load is taken by means of through bolts relieving the cast-iron framing of tension stress (Figs. 12 to 14). (3) The engine carried entirely on a system of through bolts and turned-steel columns suitably reinforced by bracing. In Fig. 15 the cast-

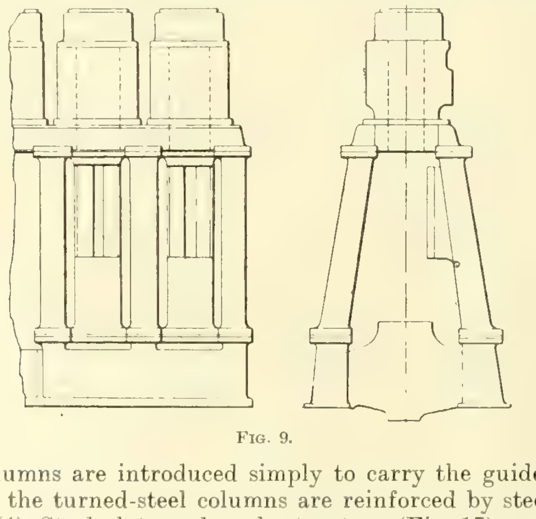


FIG. 9.

iron columns are introduced simply to carry the guides. In Fig. 16 the turned-steel columns are reinforced by steel castings. (4) Steel plate and angle structure (Fig. 17).

In this all-important question of type of framing, steam-engine experience is, of course, invaluable, but lessons therefrom are in no way conclusive unless the pressure and load differences are thoroughly investigated and appreciated. The manner in which the author has attempted to show this is given in Figs. 18 to 21. Fig. 18 shows the guide loads for steam and oil engines having similar initial piston loads. In Table II. are stated the calculated values of the bending moments from these loads for a standard engine column; from these data the bending moment has been drawn for any position of the working stroke and for any point on the column (Fig. 19). By obtaining the moduli of the sections, as shown in Fig. 20, the stress in any section can be obtained, as seen in Fig. 21, both for the steam and the oil engine.

Whereas with the steam engine the stress varies from plus 800lbs. to minus 600lbs. per square inch, with the oil engine the variation is from plus 370lbs. to minus 340lbs. per square inch for the same tension load. In this way the ratio of the

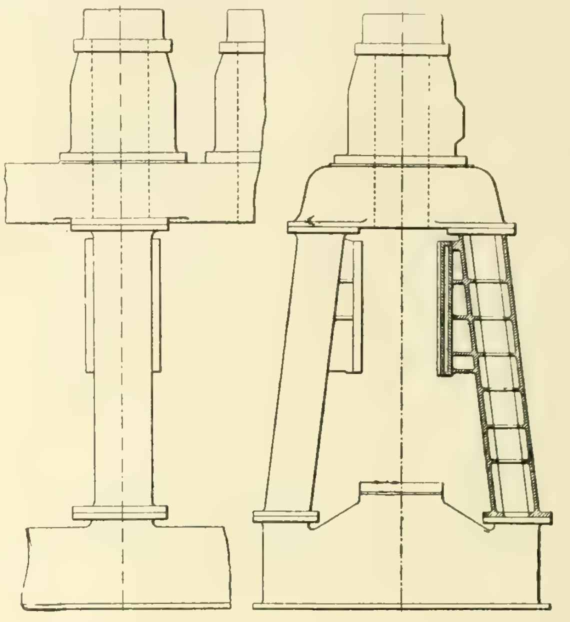


FIG. 10.

bending to the tension load with steam engines is 0·15, compared with 0·082 with oil engines, showing that relatively the tension load is of greater importance in the case of the oil engine, and that, in consequence, the steam-engine framing cannot be advocated for the oil engine with the same force as for the steam engine.

Partly in view of the foregoing, a system of taking the tension direct from the cylinder to the bedplate would seem to be essential for large engines, not only from the point of

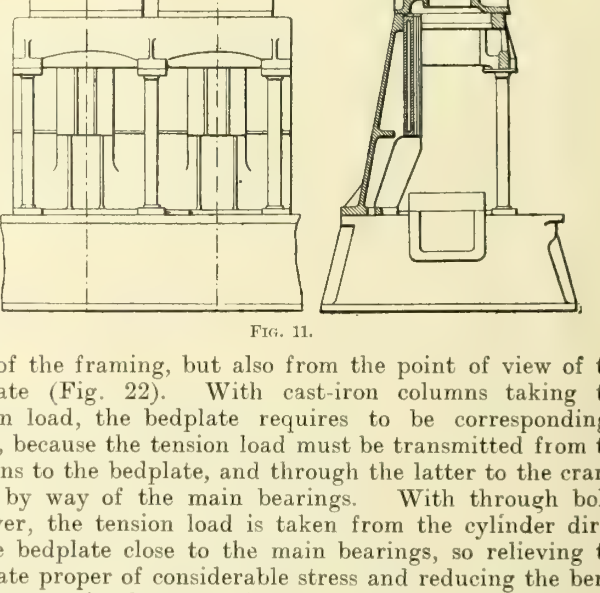


FIG. 11.

view of the framing, but also from the point of view of the bedplate (Fig. 22). With cast-iron columns taking the tension load, the bedplate requires to be correspondingly stiffer, because the tension load must be transmitted from the columns to the bedplate, and through the latter to the crankshaft by way of the main bearings. With through bolts, however, the tension load is taken from the cylinder direct to the bedplate close to the main bearings, so relieving the bedplate proper of considerable stress and reducing the bending moment in the cross girders to about two-fifths of that without through bolts.

* Paper read before the Junior Institution of Engineers, April 20th, 1914.

When the design of cylinder head permits, the spacing of the through bolts should be such as to reduce to a minimum the bending moment (*a*) between the seating and the through bolts, and (*b*) between the two through bolts. The curves (Fig. 23) show this, and also that, whereas it is convenient

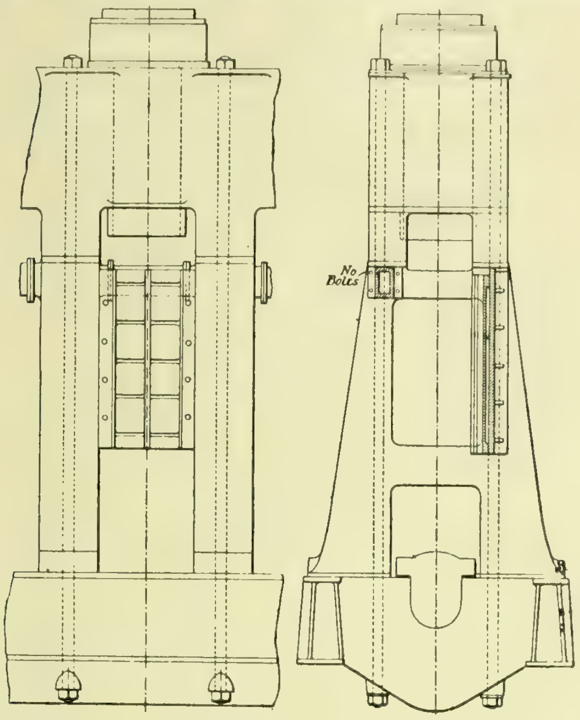


FIG. 12.

to make the bedplate of deep and strong section underneath the crank shaft, its strength rapidly diminishes to accommodate the seating towards the point of fixing at the seating. Table III. gives values in practice and the approximate values of the bending moment for different ratios of $a/1$.

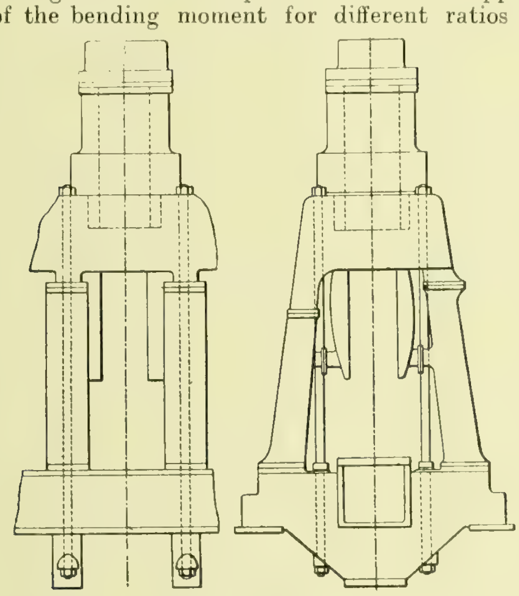


FIG. 13.

The advantages of this method in reducing the bending moment are obvious.

The construction of the future would seem to require through bolts, either from the cylinder head or the cylinder itself from above the exhaust and scavenging ports to the bedplate in way of the crank shaft. Another very important advantage with through bolts to the cylinder head is the fact that the cylinder is relieved of all tension stresses. This forged-steel structure may require to be reinforced by some form of cast structure for stiffness and to carry the guides; but to what extent and of what nature it is difficult to foresee, as the question of vibration due to lack of balance is one best settled by experience.

In view of the number and variety of types of framing at present advocated and built, as illustrated in Figs. 8 to 17, it may be inferred that the design of the future is an entirely open question.

Crank Shafts.—The strength of the crank shaft is to some considerable extent proportional to the strength of the crank webs, as failures with multiple crank shafts have most frequently occurred in this section.

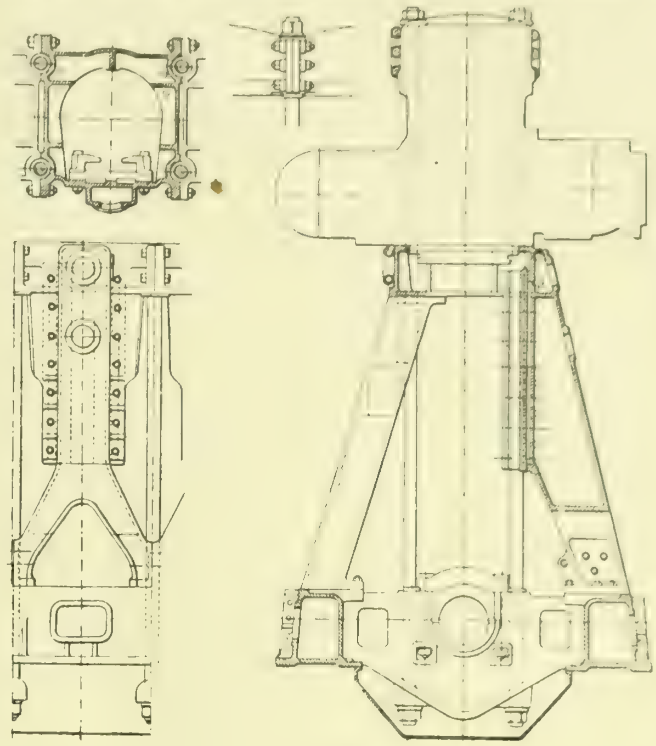


FIG. 14.

To estimate accurately the actual stress in a crank web of a multiple-crank engine is exceedingly difficult. The following formula for web thickness is suggestive, and gives limiting values for the web

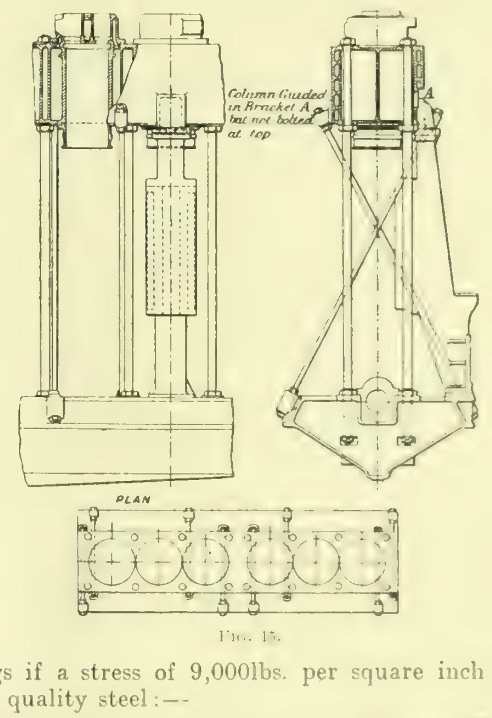


FIG. 15.

scantlings if a stress of 9,000lbs. per square inch be taken for good quality steel:—

$$f = \frac{590\ D^2\ R}{b\ t^2} + \frac{196\ D^2}{b\ t} + \frac{T\ max. - T\ max.\ d/S}{b\ t}$$

in which—

f = stress pounds per square inch.
D = diameter of cylinder in inches.
R = length of crank pin in inches.
b = breadth of web in inches.
t = thickness of web in inches.
d = diameter of crank shaft in inches.
S = stroke of crank shaft in inches.
T max. = Maximum turning moment, 63,030 b.h.p. × K / N.
N = revolutions per minute.
K = ratio T max. / T mean.

This formula gives the summation of the three types of stresses in this part. The first term represents the stress due to the piston load acting directly through the crank pin. The second is merely that of crushing, and the third is that due to the transmission of the torque. For crank shafts of four or less cranks, the first term is by far the most important, so

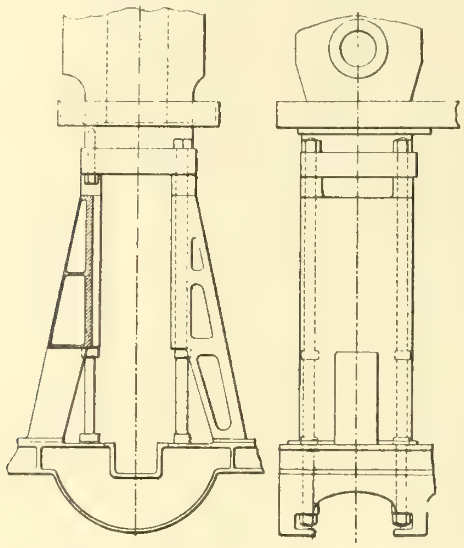


FIG. 16.

that, roughly, the strength of the crank web may be stated as being proportional to $b\ t^2$.

Crank webs may be calculated upon the basis of the twisting of square shafts, but the data on this subject are very meagre. The strength of the crank web should, of course, be equal to the strength of the crank shaft, and if it can be stated that in usual Diesel engine practice the thickness t is

tion that, with four-cycle practice, the breadth of the web is a greater multiple of the thickness than with two-cycle engines. This is due to the spreading out of the cylinder centres with two-cycle engines in order to accommodate the exhaust belt.

The next curve, Fig. 25, shows, as would be expected, that the thickness of the web is proportional to the diameter of

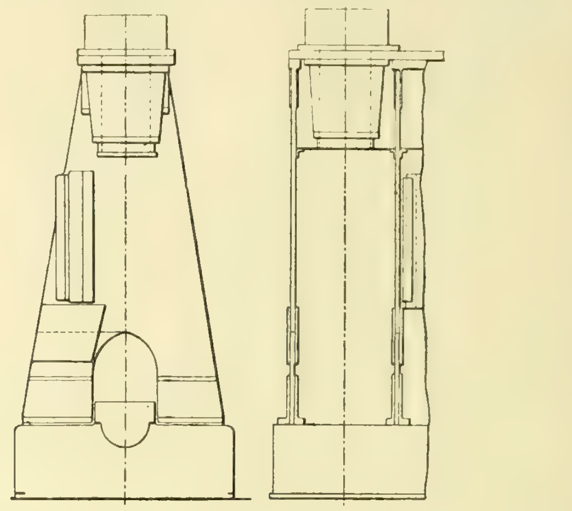
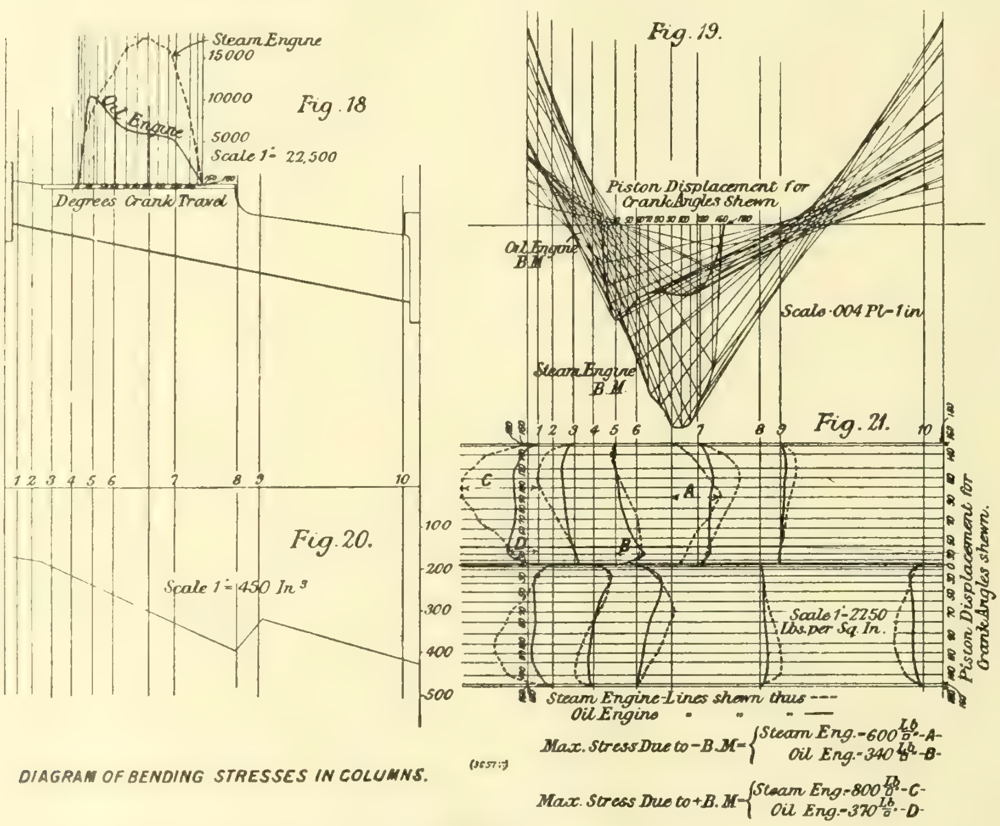


FIG. 17.

the shaft, and the law, as seen from the curve, is: $t = 0{\cdot}545\ d$ for two-cycle engines, and $t = 0{\cdot}482\ d$ for four-cycle engines.

If it be assumed that the stroke of the engine is proportional to the diameter of the cylinder, then the power developed by the engine, or the forces acting upon the crank shaft, are proportional to the diameter of the cylinder cubed, *i.e.*, D^3, in which case the diameter of the shaft should be



FIGS. 18–21.

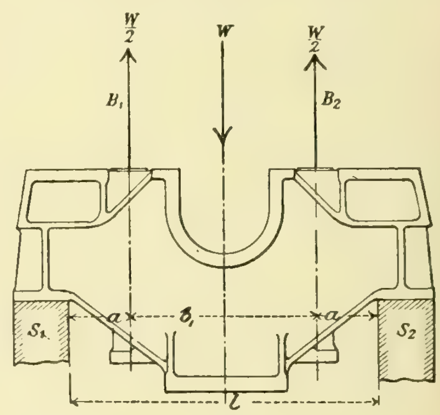


FIG. 22.

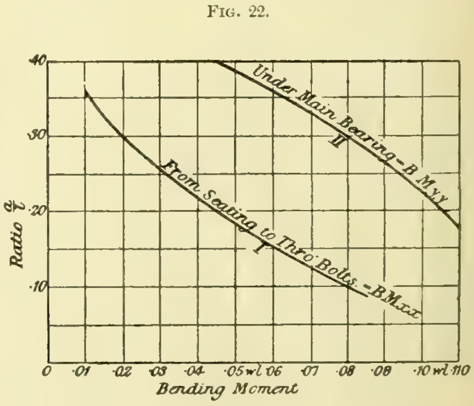


FIG. 23.

proportional to the breadth b, then $b\ t^2$ should be proportional to d^3, where d is the diameter of the crank shaft, and t proportional to d. In Fig. 24 it is shown that t is roughly proportional to b, the law being: $t = 0{\cdot}434\ b$, or $b = 2{\cdot}3\ t$.

The curves shown in Figs. 24 to 27 are made up from a number of engines representing current practice. The figure above the points in this and subsequent curves dealing with crank shafts refers to the number of cylinders, and a star refers to high-tensile steel. These are not informative, but the hollow points, as opposed to the full points, give indica-

proportional to the diameter of the cylinder, and the curve (Fig. 26) shows that this is approximately true for two-cycle and four-cycle engines of four, six, and eight cylinders, in which $d = 0{\cdot}58$ D.

In the foregoing, so nearly do the curves approximate to a straight line that it would seem that the theoretical supports for the crank shaft must be spaced equally in proportion to the cylinder diameter, and the curve (Fig. 27) shows this to be approximately the case where $D = 0{\cdot}472$ L (length between bearing centres) or $L = 2{\cdot}12$ D.

For working out crank shafts to a first approximation, without taking into account the question of balance, method of drive of scavenging pumps, or whether the compressor is

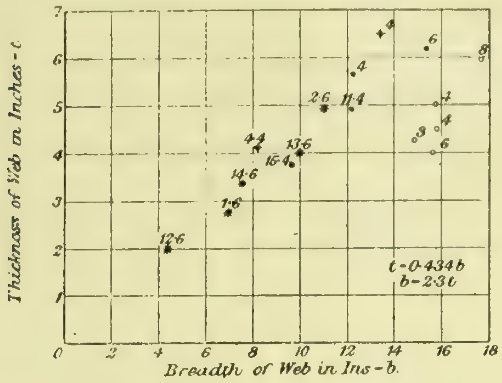


FIG. 24.

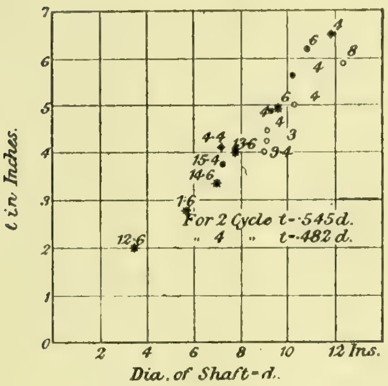


FIG. 25.

driven from the engine, the crank shaft rule of the British Corporation for the Survey and Registry of Shipping* works out very well for the great majority of cases.

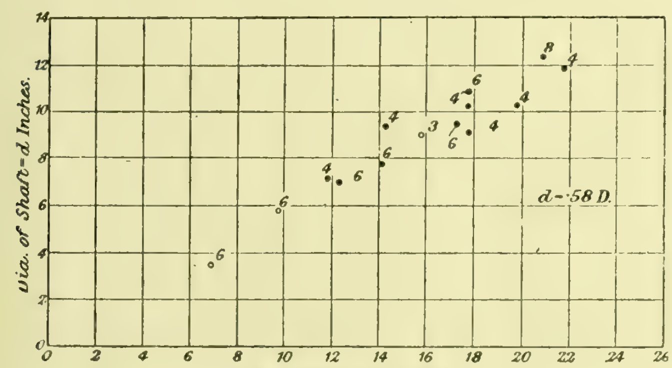


FIG. 26.

* At present this rule is, with other oil engine recommendations, before the Technical Committee of this Society for consideration and possible amendment.

For crankshafts, $d = \sqrt[3]{\dfrac{D^2 \times P\,(S + L)}{C}}$

when :—

- d = diameter of shaft in inches.
- D = diameter of cylinder in inches.
- S = stroke of piston in inches.
- L = length between edges of bearings in inches.
- P = maximum initial pressure lb. per square inch.
- C = constant.

C.	For four-cycle engines. Single acting. No. of cylinders.	For two-cycle engines. Single acting. No. of cylinders.
·9000	1, 2, 3, 4.	1, 2, 3.
·8500	6	4
·8000	8	—
·7500	12	6
·7000	—	8
·6000		6†
·4500	- -	8†

† These apply to cases where the cranks are so arranged that two impulses occur simultaneously.

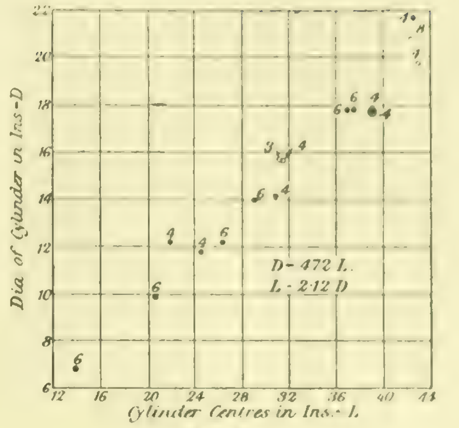


FIG. 27.

TABLE II.

Calculated Bending Moments in Engine Columns.

(See Figs. 18 to 21).

Number.	Crank Angle.	Piston Displacement.	Piston Displacement + Constant. d + c* = a for B.M. equation.	Guide Force. F = [illegible] ton and P. P = Piston Load at Crank P.	Values of P. W in B.M. equation in terms of initial Piston load P (on 500 lbs. sq. in. basis.)	B.M. [illegible]
		d. ins.	ins.			
1	10	·285	16·785 = $\frac{1}{5·35}$ †	·0384 P	P_1	·00293 P_1 l
2	20	·975	17·475 = $\frac{1}{5·15}$	·0761 ,,	1·015 ,,	·00608 ,,
3	30	2·15	18·65 = $\frac{1}{4·81}$	·1116 ,,	·94 ,,	·00902 ,,
4	40	3·64	20·14 = $\frac{1}{4·46}$	·1441 ,,	·71 ,,	·00895 ,,
5	50	5·5	22·0 = $\frac{1}{4·08}$	·1724 ,,	·515 ,,	·00818 ,,
6	60	7·6	24·1 = $\frac{1}{3·73}$	·1956 ,,	·372 ,,	·00715 ,,
7	70	9·85	26·35 = $\frac{1}{3·41}$	·2132 ,,	·305 ,,	·0067 ,,
8	80	12·222	28·72 = $\frac{1}{3·13}$	·2238 ,,	·267 ,,	·00647 ,,
9	90	14·4	30·9 = $\frac{1}{2·9}$	·2281 ,,	·261 ,,	·00675 ,,
10	100	16·7	33·2 $\frac{1}{2·71}$	·2238 ,,	·261 ,,	·0068 ,,
11	110	18·7	35·2 = $\frac{1}{2·55}$	·2132 ,,	·267 ,,	·00678 ,,
12	120	20·6	37·1 = $\frac{1}{2·42}$	·1956 ,,	·270 ,,	·00642 ,,
13	130	22·2	38·7 = $\frac{1}{2·32}$	·1724 ,,	·25 ,,	·00 ,,
14	140	23·5	40·0 = $\frac{1}{2·25}$	·1441 ,,	·238 ,,	·00423 ,,
15	150	24·7	41·2 = $\frac{1}{2·18}$	·1116 ,,	·232 ,,	·00 ,,
16	160	25·3	41·8 = $\frac{1}{2·15}$	·0761 ,,	·232 ,,	·00219 ,,
17	170	25·8	42·3 = $\frac{1}{2·12}$	·0384 ,,	·232 ,,	·00 ,,
18	180	26·0	42·5 = $\frac{1}{2·11}$	0	0	0

* c = the constant distance between the top point of fixation of the engine column, and the point of application of the guide load at the crank, top dead centre. † l = length of column in inches.

TABLE III.

Effect of Through Bolts on Bending Moment in Bedplate

(See Figs. 22 and 23).

B.H.P.	No. of Cylrs.	Diameter.	Stroke.	l	l_1	$\frac{l_1}{l}$	a	$\frac{a}{l}$	From Curve. B.M.xx.	From Curve. B.M.yy
		in.	in.	in.	in.		in.		wl.	wl.
500	4	17	24	48	28·8	·6	9·6	2	·045	·105
225	,,	11·8	17·3	37	19·5	·525	8·8	236	·035	·0972
1000	,,	21·65	31·5	62·6	31·3	·50	15·7	·25	·03125	·09375
225	,,	11·75	18	36	19·5	·54	8·25	23	·0365	·0986
850	,,	18·75	27	47	28·4	·605	9·3	·1975	·0455	·1055
1100	6	22·04	39·37	89	31·2	·35	28·9	325	·0155	·072

(To be continued.)

STARTING DEVICE FOR INTERNAL-COMBUSTION ENGINES.

ONE of the inconveniences attending the use of internal-combustion engines is their want of flexibility. For instance, when it is required to start large engines, or when the engine is misfiring or is temporarily overloaded, it is necessary to assist the engine from an additional source of power to maintain the requisite pressure in the cylinders. To obviate this, Mr. L. A. C. Letombe, 46, rue de Londres, Paris, has designed and patented the device illustrated herewith, by means of which the flexibility of an internal-combustion engine is automatically increased at the moment of starting, or in the case of an excessive overload being placed on the engine, by an automatic admission of an auxiliary fluid such as compressed air or vapour, which is supplied to the several cylinders of the engine by means of a balanced valve temporarily unbalanced under the influence of the engine governor, this auxiliary driving medium being of course maintained at a pressure higher than that which can be attained by the combustion of the charge in the cylinder in the event of the engine being subjected to temporary overloading.

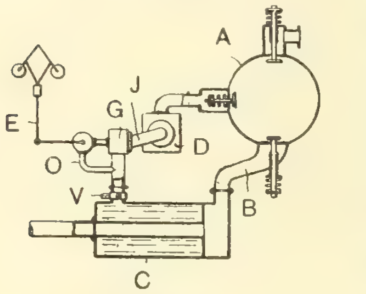


FIG. 1.

A general diagram of the arrangement is shown in Fig. 1. A represents the internal-combustion engine; B is the exhaust pipe, the gases issuing from this pipe passing into the smoke tubes of the steam generator C. The steam supply pipe of this generator is connected with an apparatus D for the distribution of the additional fluid, running synchronously with the distributing gear of the engine. This distributor is controlled by the governor E of the engine by the intermediary of a valve, in such a manner that it does not distribute additional fluid until the revolutions fall below a minimum limit.

Fig. 2 illustrates in detail a constructional form of distributor for additional fluid combined with an admission valve

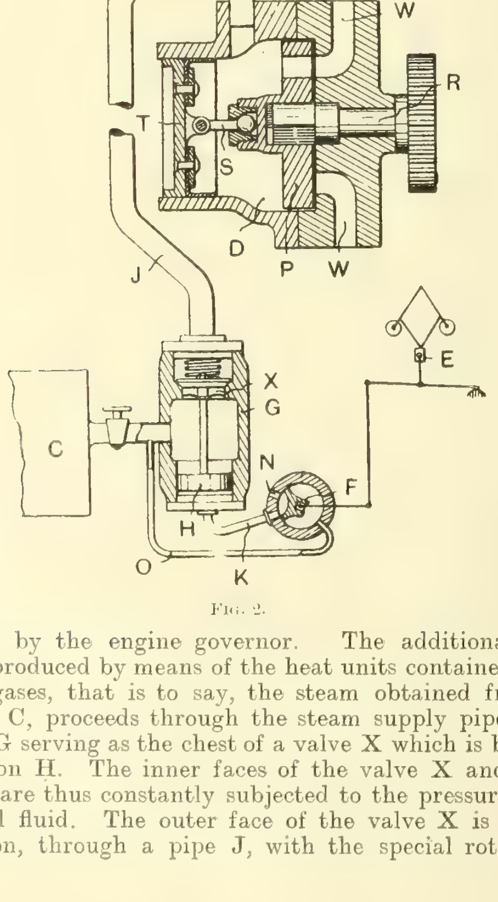


FIG. 2.

controlled by the engine governor. The additional fluid, which is produced by means of the heat units contained in the exhaust gases, that is to say, the steam obtained from the generator C, proceeds through the steam supply pipe into a chamber G serving as the chest of a valve X which is balanced by a piston H. The inner faces of the valve X and of the piston H are thus constantly subjected to the pressure of the additional fluid. The outer face of the valve X is in communication, through a pipe J, with the special rotary distributor D. The outer face of the balancing piston H is in communication, through the pipe K, with the chest of a valve F controlled by the governor of the internal-combustion engine. Normally, that is to say, when the engine is running without excess load, the valve F places the pipe K in communication with the atmosphere through an orifice N. When, on the other hand, the resistance increases, or when the speed and therefore the governor drops, for any other reason, below a predetermined position, the position of the valve F is altered and it cuts off communication between the pipe K and the atmosphere and establishes communication between the pipe K and a pipe O connected with the generator C. So long as communication exists between K and N, the pressure of the additional fluid upon the piston H maintains the valve X closed. When, on the other hand, communication is established between K and O, the piston H is subjected to the pressure of the additional fluid upon both its faces, in such a manner that the valve X is able to open under the influence of the fluid entering through the steam supply pipe, thereby admitting the additional fluid to the distributor D. The distributor is so constructed that it does not bear upon its slide face except when performing useful work. With this object it comprises a distributor disc P having an orifice which comes in succession opposite the pipes W, opening into the several cylinders of the engine, through non-return valves. This distributor disc is able to slide upon the square end of a shaft R rotating synchronously with the distributing shaft of the engine. In order to avoid excessive friction of the disc P upon its slide face, the disc is connected, by means of a jointed rod S, with a piston T subjected upon its inner face to the pressure of the additional fluid to be distributed and upon its outer face to atmospheric pressure. The surface area of the distributor disc being greater than that of the piston, the pressure of the additional fluid presses the disc against its seating, but with less force than if the piston T were not used, since the fluid also tends to push the piston away from the disc seating, whereby the pressure on and the friction between the disc and its seating is reduced. The ball joint connection between the rod and the disc P allows the latter to rotate freely without entailing any rotation of the balancing piston. When the distribution of the additional fluid ceases, owing to the return of the governor E to its position for normal operation of the engine, the disc P separates from its slide face under the influence of friction during the last few revolutions that it makes, by sliding upon the squared end of the shaft R. When the disc recedes towards the exterior the ball joint loses its support upon its socket in such a manner that the disc P rotates without bearing upon its slide face or upon the ball joint.

The general installation as shown in Fig. 1 comprises a valve V for the supply of the additional fluid, which valve is arranged upon the additional fluid reservoir or upon the generator C. In order to start an engine it can be driven exclusively with the additional fluid by opening the cock V for that purpose, and then leaving it open for normal running, the admission of fluid taking place as soon as the valve V is open, because at this moment the governor E is at the lowest point of its travel.

Association of Mining Electrical Engineers: Yorkshire Branch.—The annual meeting of this branch was held a few days ago at Leeds. Officers for the next year were elected as follows: Branch president, Mr. John C. Crawshaw, Ridings Colliery, Dewsbury; vice-presidents, Prof. F. E. Armstrong, Sheffield University, and Mr. C. L. Robinson, H.M. Inspector of Mines, Leeds; branch editor, Mr. A. R. Chaytor, Yorkshire Electric Power Company; auditor, Mr. A. E. E. Pelley; hon. secretary and treasurer, Mr. J. A. McLay; branch council, the above officers and Messrs. R. Holiday, H. C. Jenkins, F. Mellor, J. Bentham, H. Elliott, F. Marsland, and T. Charlton. It was decided to accept the invitation of Mr. Holiday to visit Acton Hall Colliery on the last Saturday in May, to arrange a visit to the Manchester Mining Exhibition in June, and, subject to the invitations being extended, to visit the New Silkstone and Haig Moor Collieries, near Castleford, in July, and the Yorkshire Electric Power Company's new station in September. A paper by Mr. Fred Smith (Pinxton Collieries) dealing in a practical manner with "Repairs to Electrical Plant" in collieries was read and discussed.

THE EMBRITTLING OF IRON BY CAUSTIC SODA.

A paper on "The Embrittling of Iron by Caustic Soda," by Mr. J. H. Andrew, was communicated to the Faraday Society on April 22nd last. Small flat specimens of wrought iron, rough filed and highly polished, were immersed in a concentrated aqueous solution of caustic soda at 100° C. for periods lasting over several months. The specimens were examined from time to time, and it was found that: (1) The initial corrosion of the polished metal was less than that of the unpolished, but eventually both became highly crystalline, the surface of the two being similar, and their corrosion rate was approximately the same. The recrystallisation of the specimens caused them to become extremely brittle; the brittleness eventually disappeared, however, with prolonged immersion, and during the treatment with soda, hydrogen gas was evolved.

The rate of corrosion of wrought iron increased with time, attained a maximum and then decreased, the corrosion, after a very prolonged immersion in caustic soda, being extremely slight. It had been suggested that the corrosion was due to the iron being constituted of two phases, a crystalline phase and an amorphous phase, which surrounded the crystals, and bound them together. It was suggested that when a duplex metal of this nature was immersed in an aqueous solution of caustic soda, electrolysis set in, iron going into solution at the anode, and hydrogen was liberated at the cathode, whilst sodium ferrite was formed in solution. The hydrogen after giving up its charge at the cathode, was partially liberated and partially occluded by the metal. It was the occlusion of, and diffusion into, the interior of this hydrogen which brought about crystalline growth and brittleness in the metal, the hydrogen being first absorbed by the amorphous film existing between the crystals, thereby forcing the crystals apart. When both the amorphous and the crystalline metal had become saturated, or partially saturated, with hydrogen, the metal might be considered as constituting a hydrogen cell, the potential difference depending upon the concentration of the hydrogen in the two phases; this would be less than the potential difference between the two metallic phases, and the corrosion would diminish.

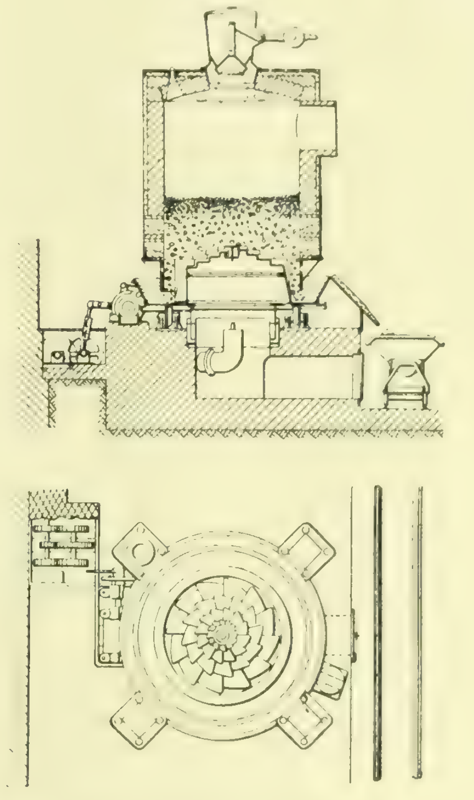
The decrease in brittleness after prolonged immersion was probably due to an equilibrium between the hydrogenised phases being established, the initial brittleness being due rather to the molecular rearrangement of the metal brought about by occlusion and evolution of hydrogen, rather than to the mere presence of hydrogen in solution. It was quite possible that the original amorphous material was destroyed, new amorphous material eventually being formed. Experiments were carried out with the idea of showing that hydrogen actually did diminish the rate of corrosion. An electrolytic iron was heated to 1,000° C. in hydrogen, and allowed to cool in the gas. The specimen after this treatment corroded extremely slowly, whereas another sample of the same material untreated corroded at the normal rate.

It might be concluded from these experiments that the passivity of iron produced by immersion in caustic soda was due to the decrease in potential difference between the crystalline and amorphous phases, produced by occlusion of hydrogen. A 0·5 per cent. carbon steel was affected to a much less degree by caustic soda solution. The recrystallisation of electrodeposited iron found by Stead and Carpenter to occur when the metal was allowed to slowly cool through the A_{r3} critical point, was explained upon the basis of hydrogen evolution; as the iron cooled through the critical point the evolution of hydrogen affected a recrystallisation of the metal.

The Junior Institution of Engineers: North-western Section.—On Friday, the 1st inst., at an informal meeting of the North-western Section of the Junior Institution of Engineers, a discussion was opened by Mr. J. M. Bailey (of Messrs. The British Westinghouse Electric and Manufacturing Company, Ltd.), on "Steam Turbines." The speaker briefly touched on the early history of the subject, and a long reference was made to the work of Parsons. The progress of the last 15 years was outlined, and the merits and troubles of the Rateau, Zoelly, and Laval machines were dealt with; the aid given to progress by the condenser being noted.

REVOLVING GRATE GAS PRODUCER.

The April issue of the "Journal of the American Society of Mechanical Engineers" contains a description of a revolving grate gas producer recently introduced by Messrs. de Fontaine and Co., Hanover. The gas producer is shown in the accompanying cuts, and consists of a round shaft made of fire-proof brick and jacketed with wrought iron sheets. On top it has a charging device operated either mechanically or by hand; at the bottom, a grate, centrally rotatable, consisting of a cast-iron ash seal with the grate structure in the middle. The ash seal is filled with water in the usual manner so as to seal the inner part of the shaft away from the atmosphere. It has a worm thread on its inner surface placed spirally in stages, ending in blade-shaped surfaces, backwards, in the direction of rotation. The most peculiar part of the construction is the central grate structure provided with worm gear shaped stages and jaws. On the surfaces which distinguish the jaws and form the front surface of each jaw stage are



Revolving Grate Gas Producer.

located the outlet openings for the blast. The worm-thread grate, with its stages, gradually lifts and lowers the fuel column and thereby prevents the formation of cavities and suspended slag in the zone of gasification. Further, the jaws break up the slag which might accumulate between the grate and the bottom of the shaft, which is helped also through the bearing ring of the producer jacket being also provided with worm thread opposite to those of the grate elements. The worm thread of the bearing ring and of the grate elements therefore form a sort of conveying device for the slag.

An important element for the uniform operation of a rotary grate gas producer is to hold open constantly the outlet openings for the blast. In older constructions this was done by fitting these openings with special covers, but this had the disadvantage of permitting the flow of air downwards only, on account of which only a comparatively small grate area and high blast pressure could be used. Since in the present gas producer the blast openings are located in the undercut front surfaces of the jaws, a very advantageous grate area is obtained, while the blast can be directed upwards without any danger of the outlet openings being clogged up; since the grate moves in a direction opposite to that of the blast slots, the slots are at all times kept free from ashes and slag which might be deposited over them. A further important advantage of this design is that the blast openings are distributed over the entire shaft cross-section with extreme uniformity.

THE DEVELOPMENT OF DRY-CLEANING IN BLASTFURNACE GAS PURIFICATION.*

BY FRITZ MÜLLER.

AT the International Congress of Mining, Metallurgy, Applied Mechanics, and Practical Geology in Düsseldorf in 1910, I drew attention for the first time to the results obtained by the practical application of a new process of dry gas cleaning, which was first carried out in a large experimental plant dealing with 175,000 cub. ft. of gas per hour, this plant being situated at the Halbergerhütte at Brebach, near Saarbrücken, Prussia. Since then a great number of industrial installations, including many of large capacity, have been erected and put into operation, and others are in course of erection. The first large plants were started in 1911, and are still at work, giving the greatest satisfaction to their owners. The results obtained with these are of sufficient interest to record.

The gas coming from the blastfurnace contains about 10 to 20 grammes of dust per cubic metre, the heaviest particles of which, and therefore the richest in iron, separate first and are deposited in big dust catchers or mains, from which the accumulations can easily be drawn off whilst working. This dust, which contains a considerable proportion of iron, is either agglomerated or briquetted, and is charged again into the blastfurnace. On its way to the cleaners the crude gas is cooled down approximately to the dew-point in a surface cooler placed in front of them; if the temperature of the gas is very high, or in hot weather, the efficiency of this surface cooler is increased by the injection of finely-sprayed water.

If water injection is not feasible for any reason, an apparatus with cooling tubes similar to the well-known economiser can be used. After passing the cooler, the crude gas, which still contains more than 5 grammes of dust, is led through a superheater, where by means of steam or burnt waste gases its temperature is raised by some 10° to 20° C. The superheated gas then rises through a distributing pipe into a system of filter-boxes, the number of which depends upon the size of the plant. In the different chambers, which can be shut off from one another independently, filter-bags made of special cloth are suspended. The lower end of each bag is fastened in a frame in the bottom of the compartments, whereas the upper closed end is suspended on a movable cross-bar, which keeps the bag stretched during working. The crude gas is drawn by exhaust fans into the interior and through the cloth of the bags, to the inside of which the dust remains clinging. The cleaned gas is passed straight on by the fans to its destination without any further treatment, except that the gas used for driving gas engines must first be water-cooled. The dust deposits in the inside of the bags, and it is therefore necessary, in order to prevent their complete choking, to shut off and automatically clean each chamber at regular intervals. A special mechanism shakes the bags, whereby part of the dust is removed, and at the same time a stream of clean gas at a higher pressure than that of the crude gas current is blown in the opposite direction through the bags, that is, from outside to inside. This operation removes the last trace of dust still sticking to the bags. The dust falls into a screw conveyer, which carries it on to the dust boxes, whence it is discharged at intervals into wagons placed below; this process is quite automatic. The cooling down of the gas to nearly the dew-point ensures that the cloth of the filter bags will not be destroyed by the heat, and on the other hand the slight superheating prevents the condensation of vapour when the gas is passing through the bags, so as to avoid choking them up.

Trials lasting several years were made by the Halbergerhütte, in conjunction with the engineering firm Beth of Lübeck, before the process was perfected sufficiently to meet the requirements of practical working. The general lay-out of the first plant has been preserved in those of latest design, but many improvements in detail were introduced after the experience obtained in practical working by the Dingler'sche Maschinenfabrik A.G. at Zweibrücken. What will chiefly interest the practical man are the results obtained by the new process. In the first place, the gas is of a higher purity than has ever before been obtained by any other cleaning system; secondly, the working costs are very low owing to the low power and water consumption.

* Paper read before the Iron and Steel Institute, May, 1914.

The gas after passing the filter chambers generally contains about 3·5 milligrammes of dust per cubic metre, which falls below one milligramme when the gas is cooled down with water to serve for gas engines. No water is injected into the fan, and the latter has therefore only to overcome the resistance of the filter-bags. Consequently its power consumption is far lower than that of corresponding fans in wet-cleaning processes. Tests carried out by Prof. F. Mayer, of Aix-la-Chapelle, on the plant of the Halbergerhütte show that for the actual cleaning process the power consumption is 1·91 h.p. per 1,000 cubic metres of cleaned gas, the gas being taken at 0° C. and 3·0in. of mercury. For an increase in pressure corresponding to 4in. water gauge, the power consumption increases by 0·81 h.p. per 1,000 cubic metres of gas. Very striking was the difference of power consumption of a large new plant in the Minette district in comparison with that of a wet-cleaning plant which it replaced. The wet-cleaning plant for gas engines required 350 h.p., which dropped when starting the dry-cleaning plant to 70 h.p. The quantity and pressure of gas was the same in both cases, while the dust content of the gas fell to 2·5 to one milligramme per cubic metre of gas. Some data concerning older cleaning plants

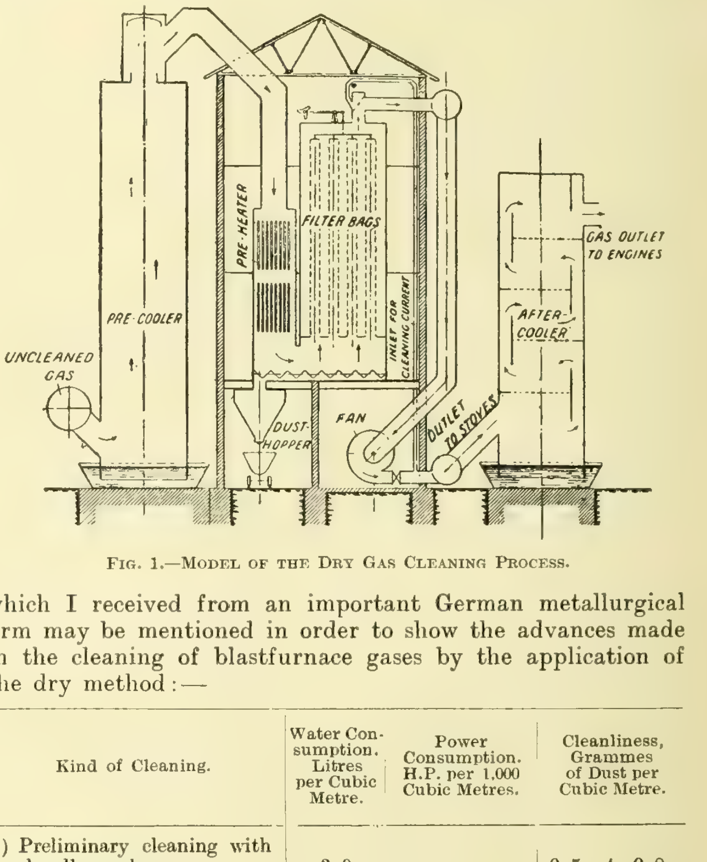


FIG. 1.—MODEL OF THE DRY GAS CLEANING PROCESS.

which I received from an important German metallurgical firm may be mentioned in order to show the advances made in the cleaning of blastfurnace gases by the application of the dry method:—

Kind of Cleaning.	Water Consumption. Litres per Cubic Metre.	Power Consumption. H.P. per 1,000 Cubic Metres.	Cleanliness, Grammes of Dust per Cubic Metre.
(*a*) Preliminary cleaning with hurdle washers..........	3·0	—	0·5 to 0·8
(*b*) Secondary cleaning in the fan	1·5	2·5 to 3·0	0·1 „ 0·3
(*c*) Secondary cleaning in the Theisen washer	2·0	7·0 „ 7·5	0·013 „ 0·2

It should be noted that the figures under (*a*) are for so-called preliminary cleaned gas containing 0·5 to 0·8 gramme of dust per cubic metre, which was then treated by the processes under (*b*) and (*c*). The figures given there have to be added to be compared with the figures for dry cleaning.

As to American conditions, I am able to give the average results of several years' working at the cleaning plant of the Illinois Steelworks. There the gas is first treated in hurdle cleaners with large quantities of water, namely, 11 to 12 litres per cubic metre of gas. The secondary cleaning is done in

Theisen apparatus, which require 2·5 litres of water per cubic metre of gas and 8·2 h.p. per 1,000 cubic metres of gas, the degree of cleanliness obtained being about 0·014 gramme. The working costs in this case are about 2·75d. per 1,000 cubic metres of gas, redemption and interest not being taken into consideration, and the horse-power hour being calculated at 0·28 cents. Results obtained with the new wet processes—for instance, the so-called Bayer system with disintegrator—are given below, though these have not yet been verified, so far as I know:—

Wet Cleaning. Bayer System.	Power Consumption. H.P. per 1,000 Cubic Metres.	Water Consumption. Litres per Cubic Metre.	Cleanliness. Grammes of Dust per Cubic Metre.
Preliminary cleaning	2·7 to 3·2	0·5 to 2·0	0·2 to 0·4
Final cleaning	3·5 „ 4·0	3·0	0·01 „ 0·02

As will be seen, these results fall far short of those obtained with the dry-cleaning process, and personal information I recently obtained concerning a Bayer apparatus supplied to Westphalian Iron and Steel Works shows that guaranteed results were not nearly attained. The same was experienced in the case of a plant of the same kind supplied to a Russian works.

The new design of disintegrator built by Mr. Theisen, of Munich, shows, according to communications in "Stahl und Eisen," a power consumption of 5·0 h.p. to 5·5 h.p. per 1,000 cubic metres of gas, a consumption of water of 0·4 to 0·7 litre per cubic metre, and a dust content of 0·008 to 0·02 gramme per cubic metre. Though the amount of water used in this new apparatus is smaller than before, there is still the disadvantage that the cleaning water has to settle and the mud afterwards has to be removed. The consumption of water given for the Theisen apparatus is only the water necessary for washing the gas, and it is therefore necessary to cool the gas down considerably, which means a further consumption of water.

Naturally a dry-cleaning plant cannot be cheaper, as to first cost, than a wet-cleaning plant; the first cost is somewhere about £175 per 1,000 cubic metres of gas, but trials are in progress which will result in a considerable reduction of the first cost by increasing the capacity and simplifying the mechanism of the plant. On the other hand, the dry-cleaning plant has the advantage of low working costs, which are about 1d. to 1¼d. per 1,000 cubic metres of cleaned gas, without redemption and interest, the power being taken at 0·375d. per kilowatt-hour. This is without taking account of the advantages obtained by using highly-cleaned gas. Another point in favour of the dry-cleaning plant is the very small ground space required, since it extends more in the direction of height; generally not more than 4 to 5 square metres (40 sq. ft. to 50 sq. ft.) per 1,000 cubic metres of gas are required, whereas wet-cleaning plants require two or three times as much space, including the settling tanks. The dry-process plant can be easily adapted to any local conditions. In the case of a plant at an ironworks on the Saar, the apparatus is erected above the casting-bed of the blast-furnaces, no other place being available. The recovered dust is removed in a dry state, whereas in wet-cleaning plants it carries about 80 per cent. of water, which greatly increases the difficulties of handling the mud. Moreover, the wet mud cannot be utilised, whereas the dry dust, on account of its extraordinary fineness and its content of lime, can be used for many purposes, such as the manufacture of cement, the briquetting of ores, and as insulating material, &c.

The cement specialist, F. Mayer, found by systematic trials that by adding 30 per cent. of gas-filter dust to Portland cement the strength was increased, especially its resistance to pressure. Samples stored for 28 days in air, in air and water, and under water showed respectively a compressive strength of 566 kgs., 398 kgs., and 455 kgs. per square centimetre. The dust is of such fineness that it requires no further crushing; on the 5,000-mesh sieve it leaves no residue. The cubic metre of dust weighs somewhat more than 200 kgs., whereas the specific gravity amounts to 2·37. At an ironworks on the Saar the dust is used as a binder in briquetting the heavier furnace dust. At a French works, where the furnaces are making special irons, the same thing is being done. Formerly, at the last-mentioned works, purple ore was briquetted with lime; the lime is now replaced by filter dust, and the briquettes are of greater strength than formerly. In many places the filter dust contains a certain amount of alkalies, so that it can be used as a fertiliser. The saving obtained through the sale of dust represents in many works about 20 per cent. of the working cost of the plant.

The advantages of highly-cleaned gas are well known to all specialists. They are most apparent in gas engines, since by employing a gas of great purity a far greater degree of safety in working is assured. Stoppages are reduced to a minimum, thus reducing the cost for cleaning, repairs to cylinders, pistons, and stuffing-boxes. A comparison, made on a gas-engine plant of some 5,000 h.p., shows that since the introduction of the dry-cleaning process only about a fourth of the former stoppages are necessary, whereas the cost for repairs and cleaning are about a fifth to a sixth as against working with wet-cleaned gas; calculated on the horse-power the gain was of about 2s. 7d. per year. Further advantages are that misfires and early ignitions are practically done away with, and cheaper lubricating oils can be used.

In a large steelworks on the Rhine, where the crude gas pressure is extraordinarily high (up to 24in. water gauge), it is possible to convey the gas to the gas engines without the aid of any fan and without final cooling. The gas reaches the engines with a temperature of about 40° C. The engines being of ample design, work quite satisfactorily, the combustion air being in this case reduced somewhat. For cleaning the bags a small fan is specially installed. In this case, which cannot serve as a typical one, the total consumption of power per 1,000 cubic metres of gas is about a fourth of a horse-power.

Opinions are divided as to the advantages of the highly-cleaned gas with boilers. Generally it is taken that primary cleaned gas with about 0·5 gramme per cubic metre is perfectly sufficient. It is implicitly admitted, however, that this primary cleaned gas gives better results than the crude gas, and therefore there is no doubt that the results will be still further improved by burning highly-cleaned gas, which it is possible to obtain at a lower cost than the less perfectly cleaned gas.

Hoff gives in "Stahl und Eisen" interesting results on evaporation trials made in Dudelange, which show that with crude gas the evaporation drops within four weeks after cleaning the boilers from 65·5 to 47·7 per cent. This may show how advantageous it is to prevent these deposits of dust in the boiler uptakes. Evaporation trials made with crude gas in Cornish boilers at the Halbergerhütte showed an evaporation of 12 kgs. to 15 kgs. per square metre, a useful effect of 50 per cent. Comparative trials with highly-cleaned gas showed after the boilers had been working four weeks an evaporation of more than 23 kgs. per square metre, with a useful effect of 73·2 per cent. The blowing out of the boiler tubes and the frequent cleaning of the flues and mains being unnecessary, a considerable saving will result.

The conditions as regards heating the Cowper stoves are similar to those of boilers. The highly-cleaned gas mixes far more intimately with the combustion air, and therefore a more intensive combustion is obtained. If the brickwork remains free from dust deposit a far better heat transmission can certainly be obtained. The following example from actual blastfurnace practice may be cited: At the Halbergerhütte a blastfurnace of a capacity of 100 tons of foundry pig iron daily was heated by four Cowper stoves 28 metres in height by 6·5 metres in diameter. The brickwork was of the Böcker system, on account of the dust content of the crude gas which was formerly burnt. Whilst working with crude gas, blast temperatures between 900° to 950° C. measured in the furnace were obtained. At certain intervals the stoves of course had to be freed from slag and dust, and from time to time the upper layers of brickwork required to be renewed. Whilst one stove was out of work for repairs or cleaning, the consumption of coke naturally rose. After cleaning and repairing, the stoves were heated with highly-cleaned gas, and it was immediately found that three stoves

were sufficient to heat the blast, the quantity of gas burnt per stove remaining the same, or, in other words, there was saving in gas of 33 per cent. The stove is under blast for about four hours, during which time the temperature drops from 930° to 950° C. at the beginning to about 840° to 850° C. at the end. After one year's working the chequer-work was examined and was found in good condition. Any blastfurnace man can easily calculate the saving in cleaning, repairs, as well as the saving of coke, which otherwise would have been necessary during the different stoppages.

At another works in the Saar district where the blast-furnaces are also driven with cleaned gas, it was found after actual measurements over a long period that there was an actual saving of 15 per cent. of gas as against the former working with uncleaned gas. At the French works already mentioned it was found that in the manufacture of special qualities of iron, the difficulties and variations in quality ceased as soon as the dry-cleaning plant was started, thus proving that the temperatures of the blast were more equalised. Unfortunately, it was not possible to obtain more exact particulars.

Nowadays, on account of the rising price of fuel, the centre of gravity of any ironworks lies in the blastfurnace work, this being the principal power source of the works. All works are striving to use as little as possible, or even no other fuel whatever besides that used for the production of coke. This means economical working and utilisation of the blast-furnace gases, and this object is best attained by using highly-cleaned gas.

By a more suitable construction of the Cowper stoves, and by the use of more scientifically constructed gas burners, still more important advantages can without doubt be obtained. A trial made in this respect at the Halbergerhütte on a Cowper stove shows that it is possible when using the highly-cleaned gas to do away with the chimney stack. A firebrick arch was erected in the chimney above the hot-blast outlet and the chimney was filled up with chequer-work constructed in the ordinary way. The highly-cleaned gas, on being introduced with a certain pressure draws its own combustion air through a specially constructed burner, where both air and gas are very intimately mixed. The mixture of air and gas strikes a specially provided brick surface opposite the burner, and the combustion is so intense that at about 1½ to 2 metres higher than the gas entrance the temperature is about 1,200° C. The result of this trial was that the temperature of the burnt waste gases was very much reduced. As the trials are not yet finished, I am not yet in a position to present final conclusions as to the saving in gas which can be obtained in this way, and these must be reserved for another occasion.

Since the introduction of this new cleaning process three years ago, the interest shown by blastfurnace men has constantly increased. Several plants of a capacity of 240,000 to 300,000 cubic metres are now in course of construction in the Saar and Westphalian districts

BOOK REVIEWS.

The Vulcan Engineering Manuals: No. I., Steam Pipes, their Construction and Arrangement. Manchester: The Vulcan Boiler and General Insurance Company, Ltd. 8½in. by 5¼in. 108 pp. Price 1s. net.

This excellent little book on the construction and arrangement of steam pipes will, we are sure, be appreciated by all who have to deal with steam-power plant. It is probably the most exhaustive manual on this subject which has been published, and is practically a reprint of a series of articles that have appeared in "Vulcan" from the pen of one of the company's assistant engineers. There is not a phase of the subject which is not thoroughly treated upon, and the wide experience of the company has naturally placed at the disposal of the writer a fund of information which is beyond the reach of the ordinary engineer. The book is full of useful practical hints for the draughtsman, engineer-in-charge, and engine attendant, and we cordially recommend it to everyone who has anything to do with the arrangement and working of steam pipes.

A Manual of Petrol Motors and Motor-cars. By F. Strickland. Second edition, with 352 illustrations. London: Chas. Griffin & Co. 9in. by 6½in. 378 pp. Price 18s. net.

There is probably no field in mechanical engineering in which more rapid advances have been made than that relating to the construction of petrol motors and motor-cars. The progress has been so great that it has been difficult for writers on the subject to keep in step with it. The volume before us is acceptable at the present juncture, as it brings the subject well up to date at a time when practice is becoming crystallised and standardisation of design a subject of importance. The book is of a thoroughly practical character and replete with illustrations, so that the reader is never in doubt as to the meaning of the text. It is not, however, a work of mere description. The structural principles which determine the design of the various parts are thoroughly discussed so as to meet the needs of the draughtsman and engineer. The scientific information and records of tests are also instructive and valuable, while advantage has been taken of the second edition to bring this information up to date.

* * *

The Year Book of Wireless Telegraphy and Telephony, 1914. London: The Marconi Press Agency, Ltd. 850 pp. Price 2s. 6d. net.

The second year's issue of this annual contains a good assortment of interesting information regarding matters bearing on wireless telegraphy and telephony. The chronological record of the development of wireless telegraphy goes back to 1831, and deals concisely with all events from that date up to the end of 1913. There is a full account of the International Conference of Life Saving at Sea, which took place in the latter part of last year. The International Radio-Telegraphic Convention is inserted in full, and the section which contains the laws and regulations of the principal countries of the world has been brought up to date. A feature of the book is the complete list of the land and ship stations in the world, giving particulars of range, rates, hours of working, character of service, &c. This edition also contains a number of special articles. Dr. Erskine-Murray analyses topical causes of "freak communications"; Dr. J. A. Fleming writes on "Measurement of the Strength of Wireless Signals"; Mr. Arthur Hinks, F.R.S., contributes an article on "Wireless Time Signals and Longitudes"; Mr. R. G. K. Lempfert, superintendent of the Forecast Division of the Meteorological Office, discusses the application of wireless telegraphy to the collection and distribution of information regarding the weather; Mr. G. E. Turnbull writes on "Wireless Telegraphy in the Merchant Service"; and Mr. C. E. Prince on "Problems of Wireless Telephony." In addition to these there is a glossary of technical terms used in the English, French, German, Italian, and Spanish languages.

BOOKS RECEIVED.

The Amateur Mechanic and Practical Guide for the Handyman. Edited by Bernard E. Jones. London: Cassell & Co., Ltd. 9½in. by 7in. 760 pp. Price 9s. net.

How to Build up Furnace Efficiency. A Handbook of Fuel Economy. By Jos. W. Hays. Seventh edition. Chicago: Jos. W. Hays. Price one dollar.

The Mortar-making Qualities of Illinois Sands. University of Illinois Bulletin. Bulletin No. 70. Price 20 cents.

Institution of Electrical Engineers: Scottish Section.—The annual general meeting of the Institution of Electrical Engineers (Scottish Local Section) was held in Glasgow on the 21st ult. Mr. F. A. Robertson presided. The following office-bearers were elected for the ensuing year: Mr. James Lowson, chairman; Mr. David A. Starr, vice-chairman; Mr. Archibald Page, chairman of the students' section; and Mr. Joseph Taylor, hon. secretary and treasurer. The annual report, which was submitted, showed that the membership of the section was 391. A paper on "Current-limiting Reactances on Large Power Systems," by Mr. K. M. Faye-Hansen and Mr. J. S. Peck, was read by Mr. Peck.

PUMPS FOR FIRE SERVICE.*

BY EZRA E. CLARK.

THE hand and steam fire engines are all portable in character, and valuable time is often lost in bringing them to the scene of action. Manufacturing properties, particularly, are often located at such a distance from fire engine stations that prompt service is impossible. The incalculable value of a few gallons of water at the beginning of a fire became self-evident, so that pumps fixed upon the premises, connected to a water supply and a source of power, were introduced. Later these

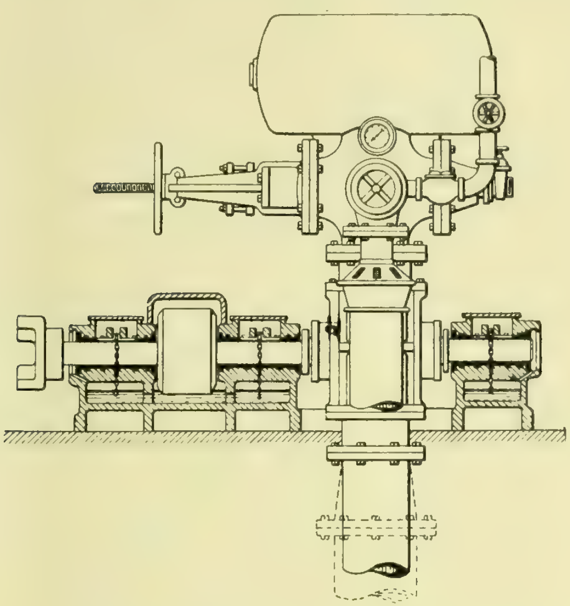


FIG. 1.—PART SECTION OF ROTARY PUMP.

were connected to a system of piping about the yard and in the mill, and the pump then became available to supply sprinkler heads, or furnish fire streams from hydrants.

In this paper, the term fire pump is to be used in its restricted sense, *i.e.*, a pump that is installed in a fixed position for fire purposes. In this sense there are three or four distinct types, generally acknowledged; rotary, duplex, centrifugal, and power pumps, any one of which, of course, could serve as a fire engine by mounting it on wheels and providing a source of power. The type of pump to be selected should be determined by the character of power available for the purpose. Naturally the most reliable source of power at any situation would be chosen, and then a pump selected that can best be driven with that power. This should be the general rule. Every type of pump, however, has its own limitations, and these must be kept in mind when studying the whole problem. The natural selection would be a pump that can run at or near the speed of the prime mover.

The earlier mills were operated almost exclusively by waterwheels and their usual speed made it comparatively easy to connect with rotary pumps. Thus, a great many pumps of this type found their way into the wheel pits of mills, although they were too often, unfortunately, poorly located. Power plunger pumps were used in a few cases, but the rotary came to be the prevailing pump, owing to its simplicity, cheapness, and adaptability to the prevailing power. Where waterwheels of ample power and moderate speed are available, the rotary type of pump becomes the logical choice, for the two can often be direct-connected, or some simple form of transmission, such as friction gears, or a silent chain having a low speed ratio can be employed. The impulse form of waterwheel with its high speed would find a better selection in the centrifugal pump, requiring no intermediate gearing. In weighing the claims of the several pumps for a situation, three things should be kept in mind: the character of the power available, the limitations of the pump, and the fact that the simplest drive is the best.

There are so many indifferent rotary pumps in mills and factories that the mere mention of a rotary raises doubts as to its value for fire purposes. Still, it should be remembered that even with the imperfect construction of the old-time cast-iron rotary, they have given some very effective service at critical times. Figs. 1 and 2 show a design of rotary pump. Several features of this design were proposed and developed by the author in 1904. They were not immediately adopted, as some experimental work was necessary, and new patterns were required. These new features were chiefly as follows: In place of the usual two sets of overhung cast-iron gears, one extra-heavy pair of cut steel gears is substituted, preferably forged solid with their shafts; these gears are supported on either side by generous bearings, and the two shafts are larger and stiffer; all bearings are provided with liberal oil reservoirs and ring or chain oilers; in place of the usual stuffing-boxes, a special form of metal water joint has been adopted, which is giving excellent service, thereby avoiding the use of perishable packing. The usual fire pump features are also provided, viz., the casing and working parts exposed to corrosion are of bronze; there are more liberal water passages; the working cams are of a new design to ensure reasonably smooth running; and the usual air chamber, hose connections, an approved spring relief valve and starting valve complete the arrangement. The press frame carrying the friction gear is now fitted with a heavy spring that maintains the gears in contact, and compensates for a possible lack of truth in their running. These pumps are not intended for daily service, as the wear between cams and casing would soon render them inefficient. But for the brief periods of fire service, considerations of wear are of less importance than certainty of action. Full particulars as to their construction can best be gathered by a study of published specifications. The effort has been to secure a rugged, reliable pump capable of doing hard work, resisting corrosion and withstanding abuse. These pumps cost somewhat less than a duplex pump. The limited number that are already in the field are so far giving excellent satisfaction.

Where steam is the most reliable source of power, the duplex Underwriter pump is usually the choice, because of its record of proved value. It is also much the cheapest of any steam-driven fire pump of acceptable reliability. In spite of its numerous parts, liable to derangement, this pump has been so thoroughly boiled down, so to speak, that with present-day construction it is proving to be one of the most reliable of fire protection appliances. The steam-turbine driven centrifugal pump is, of course, available for those who are willing to pay the price, but it costs approximately twice as much. Its main advantage over the duplex is its simplicity of working parts. Its disadvantages lie in the fact that a pressure of 100lbs. to 125lbs. of steam is required for good results, whereas, with a duplex pump, 50lbs. of steam is ample for ordinary fire pressures. The outfit is also subject to the same limitations as to suction lift as all centrifugal pumps. When the steam turbine centrifugal has become standardised and its price made more nearly competitive with that of the duplex, no doubt it will receive a much wider introduction.

As steam began to supplement and in cases to supplant water power in mills, steam-driven pumps were installed to help out or replace the rotary. At first the single-cylinder pump was used, but the advent of the duplex pump marked the beginning of a better machine for fire purposes. The duplex type of fire pump is so well known that it is hardly necessary to describe it, full information as to construction being available in published specifications. When the development of the Underwriter type of duplex pump was undertaken by Mr. John R. Freeman in the early nineties, he found the pump as made for the trade lacking in several features needed for fire protection. The frequent failures in the field showed mainly that improvement was needed. Pump builders did not fully realise the importance of some of the features that were demanded, and more or less opposition was encountered.

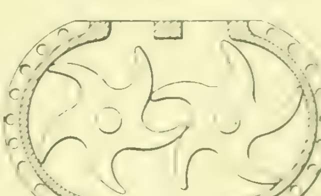


FIG. 2. WORKING CAMS OF ROTARY PUMP.

The old trade duplex pumps were found with steam and water passages restricted, but these have been enlarged in the Underwriter type, and a higher speed thus made possible. The trade pumps were iron fitted and became rusted through neglect, so that they could not be started; the Underwriter

* Abstract of paper read before the American Society of Mechanical Engineers.

pump is brass fitted wherever corrosion is liable to seize the working parts. In the older pumps, cast-bronze valve stems were used that worked loose or broke off; in the present Underwriter standard, these stems are of rolled bronze and made heavier, and the guard and nut are so secured in place by a lock devised by the author that the parts cannot work loose (see Fig. 4). In the old trade pump it was common practice to provide means of adjustment for the valve motion, and this adjustment sometimes worked loose, or was tampered with, putting the pump in a lame condition; in the Underwriter design, all adjustment has been ruled out and a simpler and more reliable mechanism is now used. Special fire service fittings are attached, such as priming valves, starting valve, relief valve, hose valves, oil pump and lubricator, all these parts having been subjected to examination and test before adoption. (See Fig. 5.)

To incorporate these changes has taken time, and it has been more or less an up-hill job. Experience, however, has shown the value of these improvements and has indicated from time to time still further improvements which have been adopted, so that to-day we have a fire pump that is able to start at a moment's notice, run at full speed if needed, and when supplied with steam, water, and oil, will run continuously and deliver its rated capacity, or more, against a fire pressure of 75lbs., 100lbs., 150lbs., or even 200lbs. in special cases.

Where the electric motor is the most reliable source of power, the centrifugal pump naturally becomes the choice.

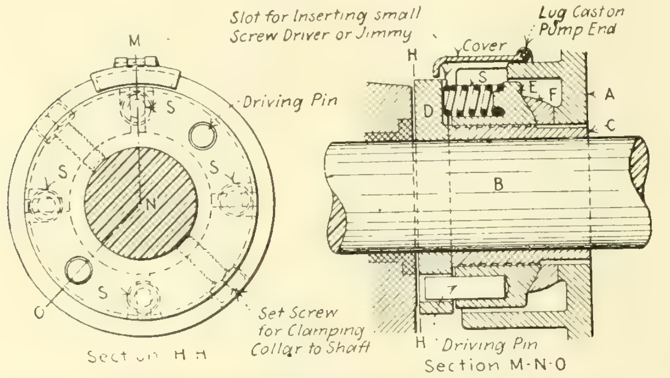


FIG. 3.—WATER JOINT USED ON ROTARY PUMP SHAFTS, AS SUBSTITUTE FOR STUFFING BOX.

The speed of a centrifugal pump can readily be made to conform to the speed of the standard motor and all intermediate gearing avoided. The direct-connected motor and pump thus form the simplest possible arrangement. It has, however, certain limitations which will be noted later, and there may exist conditions which some form of power pump electrically driven would meet with better satisfaction.

Comparatively few power pumps are in use as fire pumps, owing to their higher cost. Their best field is where a daily service pump of good efficiency is needed, that can in emergency be used for fire purposes. The triplex type of power pump is much to be preferred to the single or duplex forms, owing to its steadier discharge pressure, and as it is usually built in the vertical form the floor space required is the minimum. A strong point in favour of the triplex power pump as compared with a centrifugal is its higher efficiency, running as high as 80 to 85 per cent. for outside packed plungers as against the usual 65 to 70 per cent. for the centrifugal. That type of triplex pump employing one centrally-located driving gear is much to be preferred to those having two overhung gears. Experience has shown that the central gear drive will better ensure an even distribution of power, and thus avoid undesirable stresses on gear teeth and possible breakage. A notable example of the central gear triplex power pump may be found in the high-pressure fire service station in Philadelphia, where seven such pumps are operated by gas engines, and have given excellent satisfaction with a minimum of repairs.

The centrifugal pump is comparatively a newcomer in the fire pump field. It is distinguished from all others in being a velocity pump, the pressure varying directly as the square of the peripheral velocity of the impeller. The electric motor is no doubt responsible for its coming so rapidly into favour. The constant-speed motor direct connected to the pump makes the simplest and cheapest arrangement and affords a fairly wide range of capacities and pressures. The variable-speed motor or steam turbine, costing a little more, would place the pump more nearly on a par with the steam duplex as to range of pressures, and, the author believes, would make the preferable outfit. Its greater cost and complication is the general objection to it.

There are two types of centrifugal fire pumps built, one with the simple cylindrical case, known as the volute pump,

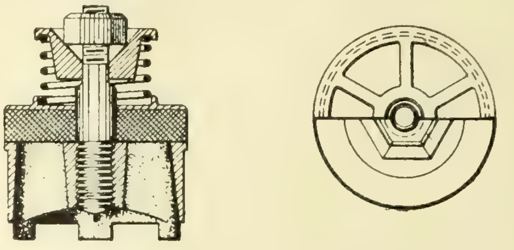


FIG. 4.—DETAIL OF VALVE STEM AND SPECIAL NUT LOCK.

and the other with a diffusion vane casing or chute case. The diffusion vane type, sometimes called the turbine pump, employs a series of gradually enlarging passages that permit a more gradual change of the velocity of the water into pressure than does the volute, thus resulting in some slight gain in efficiency. This, however, is not an essential part of an acceptable fire pump, and as the volute type of pump is much simpler in construction, and yields efficiencies that are satisfactory (60 to 70 per cent.), this type of centrifugal fire pump is being generally adopted. This type also lends itself better to the horizontal division of casing, which is preferred to the circumferential division, as it permits quicker and better access to the interior for overhauling or cleaning.

The simplicity of the centrifugal, having but one moving part, appeals to every engineer. There are no valves to choke up, no plunger to wear out, no valve motion or gears to break, and no dangerous pressures possible even with all outlets closed, unless specially provided with a variable-speed prime mover. The discharge is steady, smooth, devoid of shocks, and more nearly approximates that from a gravity supply than any other pump. But it has its limitations, which should be fully realised and considered in making an installation. Unless provision is specially made for a variable speed, its maximum working pressure is usually not planned to be very much above 100lbs. pressure, running for the smaller flows in some cases up to 130lbs. or 140lbs. Consequently the water pressure needs of a situation should be

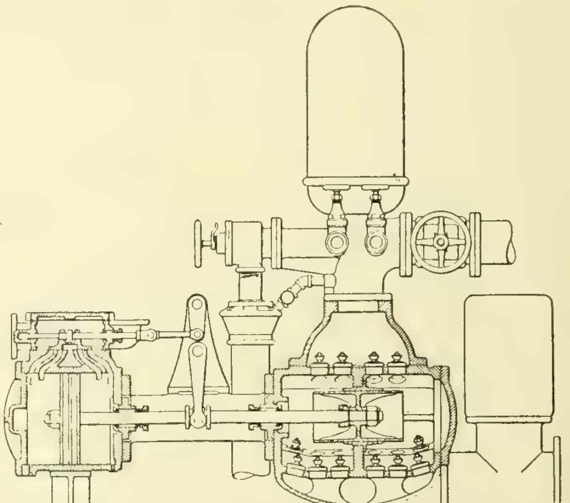


FIG. 5.—SECTIONAL VIEW OF UNDERWRITER STEAM FIRE PUMP.

carefully studied before deciding on this form of pumping outfit, and if higher pressures are needed, either a special form of impeller should be substituted or a variable speed provided.

A centrifugal has no power to exhaust the air from a suction pipe, as has the rotary, duplex, or other displacement pump. For this reason, the suction supply should come to the pump under enough head to flood the pump casing, thus

ensuring its being primed. If a lift is unavoidable, then it becomes necessary to provide a suitable foot valve and a generous supply of priming water, enough to fill completely the suction pipe and pump casing. This feature, of course, limits the centrifugal to situations where there are easy suction supply conditions.

In cost the centrifugal pump with bedplate is but little more than the duplex, but the addition of driving motor brings up the price very materially. For a given type, the speed of a motor determines its size and influences the total price of outfit. It may roughly be stated that the centrifugal pump and motor costs 50 per cent. more than the duplex. There is a wide difference, however, in the weights of the same size pump among different manufacturers.

The success or failure of a fire pump depends very much on its being properly erected and connected up. Briefly, it may be said that a fire pump must be so located as to be safe at all times from the breakage of its pipe connections due to the falling of floors and machinery, and safeguarded from any influence such as smoke, fire, or flood that might drive away the operator. It should be accessible at all times for operating and overhauling, and not blockaded by miscellaneous storage. It must permit of practicable pipe connections, the suction pipe receiving first consideration, and the steam and discharge pipes so run as to be safe from damage and always be in commission. The exhaust should go direct to atmosphere, and not be tied up with other pipes.

The suction supply should preferably be practically inexhaustible, such as a river or lake, and a suitable intake, properly screened, provided. Where a stored supply only is available, it should be large enough to supply the pump for two hours, more or less, depending on conditions. No cast-iron rules can well be established, as the insurance engineer having jurisdiction is expected to weigh conditions, and secure a reliable pump service without expensive or complicated refinements.

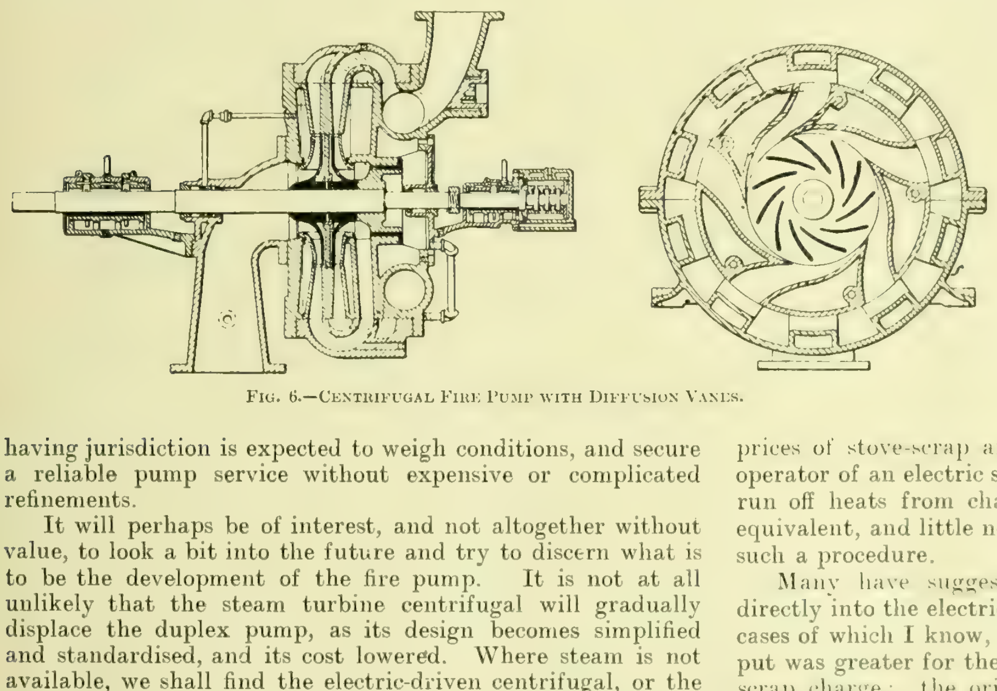


FIG. 6.—CENTRIFUGAL FIRE PUMP WITH DIFFUSION VANES.

It will perhaps be of interest, and not altogether without value, to look a bit into the future and try to discern what is to be the development of the fire pump. It is not at all unlikely that the steam turbine centrifugal will gradually displace the duplex pump, as its design becomes simplified and standardised, and its cost lowered. Where steam is not available, we shall find the electric-driven centrifugal, or the gasolene driven rotary, and as fast as its development permits, the gas-turbine driven centrifugal will possibly win recognition and receive adoption. To whatever extent insurance interests adopt these new appliances, it will be done with an eye single to their proved value, as regards simple and rugged construction and reliability of performance

New Type Metal.—The necessity of using three different metal alloys in printing establishments—one for the linotype machines, another for the monotypes, and a third for the stereotyping—seems to be obviated by a new alloy invented by George R. Wagner, chief linotype machinist of the "New York World." This alloy, according to "The Brass World," works equally well for casting whole lines of type in the linotype machines, for casting single letters in the monotype machines, and for casting page plates in the stereotyping process, and is composed as follows: Lead, 82 per cent.; antimony, 13 per cent.; tin, 5 per cent. The advantages claimed for the new alloy are that it gives to the slug or type a rigidity in excess of the metal formerly used and at much less cost.

ELECTRIC FURNACE STEEL CASTINGS.

BY C. A. HANSEN.

DURING the summer of 1911 a 3 phase arc furnace, having a nominal capacity of two tons per charge, was installed in the new and modern foundry of the Treadwell Engineering Company, Easton, Pa. The cost of melted metal from the furnace has been found to be somewhat less than one half that of the old crucible furnace plant when the latter was using oil at $2\frac{1}{2}$ cents per gallon. Since the advance in the price of oil has added \$6 to \$7 more to the cost per ton of molten crucible steel, the possibilities of saving in costs are readily apparent. So far as the product is concerned, the most striking differences are not found in comparing electric and crucible steels of similar compositions. If any differences exist between such steels they are negligible in importance, as repeated tests have shown.

Electric steel castings are usually made in lower carbons than it is possible to make from even clay-lined crucibles. In the latter it is perfectly possible to melt 0·20 carbon steel, but it is not possible to run the 0·20 carbon product regularly into light-section castings. As a result, 0·30 to 0·40 carbon castings are the usual output of the crucible steel foundry, and all castings which require machining must be annealed. With the electric furnace, furnace maintenance costs increase rapidly as the carbon content of the product is brought down, and, quite contrary to current opinion, it is not economical to turn out 0·10 carbon steel castings, although it is perfectly possible to do so. It is, however, economically practicable to turn out 0·20 carbon castings, and such castings can be machined easily without annealing. All castings, whether 0·20 carbon or 0·30 carbon, can, however, be improved by annealing.

Current opinion also has it that the advantages of the electric furnace follow largely from the fact that such a furnace can work up any sort of a charge. While this may often be true, it is not well to base estimates of the cost of molten electric furnace steel upon the usual published furnacing costs and upon the local prices of stove-scrap and similar materials. Probably every operator of an electric steel furnace has at one time or another run off heats from charges composed of stove-scrap or its equivalent, and little need be said of the reasons for or against such a procedure.

Many have suggested charging molten cupola metal directly into the electric furnace for refining. In several such cases of which I know, the power consumption per ton of output was greater for the cupola metal charge than for the cold scrap charge; the original cost of the cupola metal was in the neighbourhood of \$18 per ton, as compared with \$12 per ton for the regular cold charge, and the cost of furnacing was likewise higher for the cupola metal charge. The economy incident to heating the furnace with auxiliary fuel burning apparatus may interest those who charge molten metal into electric furnaces, but the interest attaches rather to the prevention of skulled furnace bottoms than to a direct saving in electric energy. Heating the furnace and charge to a good red heat by means of oil burners (with oil at $2\frac{1}{2}$ cents per gallon) increased the cost \$1 per ton over the regular practice of all electric heating. Keeping the furnace hot over night by means of either oil or electric energy was found not to materially decrease maintenance costs, and it did increase the cost of production. These items above refer to power supply at approximately one cent per kilowatt-hour.

Much stress has been laid on the economy attaching to continuous operation of the electric furnace as compared with

* Abstract of paper read before the American Electro[illegible] Society, April 16th 1914.

mere day-shift operation. So far as costs go for the molten steel, it is true that continuous operation means 10 to 15 per cent. saving over intermittent operation. Very little has, however, been said regarding the relative efficiencies of day and night work in the other departments of the foundry, nor has it been well impressed upon the mind of the average investigator of electric steel problems that one can easily lose many times the 10 to 15 per cent. saving in molten metal costs in the decreased efficiency of the night shifts on the moulding floor, cleaning room, &c. Claims are being made that 10 to 12 heats from cold scrap can be taken from one electric furnace in 24 hours. Possibly they can, but the furnace will have to be rebuilt at least three times each week.

These and other considerations have led to the practice, now established at Easton, of operating the foundry on day shift only, charging a good quality of steel scrap, enough pig and ore being added to keep the charge off the furnace bottom, and casting steel of around 0·20 carbon, unless otherwise specified. The furnace plant has been operated on a one-heat-per-day basis, requiring 7 to 7½ hours to turn out its charge from the cold furnace. Power consumption at furnace transformer primary terminals has, in that case, averaged 1,050 kw.-hr. per 2,000lbs. (909 kgs.) steel in the ladle.

The furnace has been operated also on a two-heat-per-day and three-heat-per-day basis, when business conditions warranted. The second and third heats, having the advantage of being started off in a hot furnace, are finished in 4½ hours, at a current consumption of 630 kw.-hr. to 640 kw.-hr. per ton. Even with the three heats per day, no steel is poured outside of the regular day shift. Two men start the furnace shortly after midnight, and steel is poured at 7-15 a.m., 11-45 a.m., and at 4-30 p.m. The uncertainties attaching to pouring on schedule time are not as great as they are with either open-hearth or crucible furnaces.

Much has been written, especially by electro-chemists familiar with direct-current electrolytic apparatus, regarding the undesirable character of the loads taken by arc furnaces. It may therefore be well to state that the load curve for the furnace here considered is smoother and of higher power-factor than the load of similar magnitude used in the shops of the Treadwell Company where the products of the steel and iron foundries are machined. It seems a pity that the electric steel furnace was not developed by people familiar with the load characteristics of modern machine tools, rolling mills, street railways, &c. Central stations are quite familiar with these loads, but they are not familiar with the arc furnace, so when we dwell upon the bad features of the arc-furnace load we can scarcely blame the central station for supposing the load-curve of the latter to be a really bad one.

Since the above was written Mr. Treadwell has sent me the following additional data concerning his furnace:—

Average number of heats per week	15
Average weight per heat, pounds	4,600
Average power consumption per 2,000lbs., kw.-hr.	900
Average repair costs per 2,000lbs.	$2.50
Average electrode costs per 2,000lbs.	$2.50
Average weight castings made, pounds	9
Ratio of cleaned castings, risers, &c., to charged weight per cent.	92·95
Ratio of finished castings to charged weight, approximate per cent.	60

The furnace lining is repaired after 35 heats.

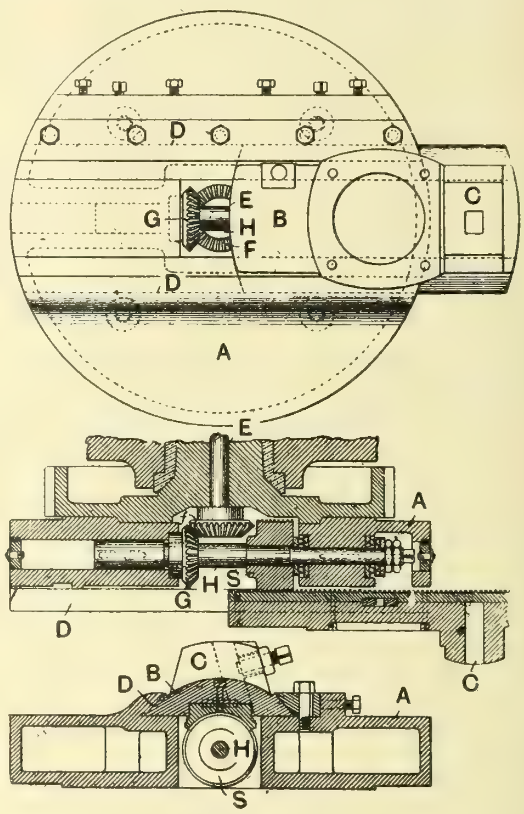
Mr. Treadwell is a firm believer in pouring extremely hot steels, and this fact is reflected in the high maintenance costs and in a rather high power consumption. A similar furnace, of which I have accurate records, shows costs as follows:—

Power consumption per 2,000lbs., kw. hr.	725
Repair costs per 2,000lbs.	$1.30
Electrode costs per 2,000lbs.	$2.15

The latter furnace is pouring somewhat colder metal into castings of 15lbs. average weight, and repairs to the furnace lining are made after 8 to 10 weeks' operation on the same basis of 15 heats per week. In the latter case the repair charges include upkeep of the bottom-pour ladles used, and I believe this is also the case with Mr. Treadwell's figure.

FACING CHUCK FOR MACHINE TOOLS.

THE accompanying illustrations show a simple arrangement of mechanism for traversing the facing slide of a facing chuck its full travel without requiring any alternative setting. The arrangement, which is the invention of Messrs. H. W. Kearns and Co., Ltd., Broadheath, Manchester, is specially applicable to surfacing, boring, and milling machines. Referring to the illustrations, A is the facing chuck and B is the facing slide having the tool holder C. The facing slide is traversed radially in undercut guides D in the facing chuck. The mechanism for traversing the slide consists of a spindle E coaxial with the facing chuck and having a bevel wheel F secured thereto. This bevel wheel is in gear with a bevel wheel G secured on a spindle H rotatably mounted radially in the facing chuck. A screw or worm S, of a diameter greater than the diameter of the bevel wheel G, is secured on the radial spindle H. This worm S is in gear with a helical rack secured to the rear face of the facing slide. The worm



FACING CHUCK FOR MACHINE TOOLS.

S can traverse the facing slide throughout its complete traverse without requiring readjustment. It is obvious that the diameter of the worm S must exceed that of the bevel wheel G to prevent the rack fouling the latter. By having a worm of greater length than that illustrated, the length of the traverse of the slide can be proportionately increased.

North-east Coast Institution of Engineers and Shipbuilders.—A lecture on "Wireless Telegraphy" was delivered on the 23rd ult. by Mr. Harry Fothergill, before this institution in Newcastle, the president of the institution (the Hon. Sir Charles A. Parsons) being in the chair. In the course of the evening Sir Charles Parsons announced the result of the ballot for the election of councillors and officers for next session as follows: President, Sir Andrew Noble, Bart.; vice-presidents, Mr. R. J. Walker, Mr. Alfred Harrison, and Mr. M. S. Gibb; five ordinary members of council, Mr. J. T. Batey, Mr. Launcelot E. Smith, Mr. G. F. Tweedy, Mr. B. G. Arkwright, and Mr. George Renwick. Awards were presented to the following graduates for papers read before the Graduate Section during the session 1912-13: C. H. Bentham, B.Sc., Wh. Ex., "The 2-cycle Marine Diesel Engine"; Moung Ba Gyaw, B.Sc., "The Transmission of Power by Chains"; E. T. Champness, B.Sc., "Oil Fuel and its Application to Marine Boilers"; M. M. Parker, B.Sc., "The General Features of Yacht Design"; and John Dickinson, "Pipe Design."

PRESENT POSITION OF DIESEL ENGINES FOR MARINE PURPOSES.*

BY J. T. MILTON.

(*Concluded from page 418.*)

APPENDIX I.—EXPERIENCE WITH VESSELS FITTED WITH DIESEL ENGINES.

THE following accounts of the services of the different vessels referred to have been mainly taken from the published shipping papers. The various vessels are arranged to some extent in chronological order, but this has been departed from when dealing with some vessels which are either sisters, or have been constructed by the same builders.

The first sea-going vessel, other than small craft, to be fitted with Diesel engines was the twin-screw Italian vessel "Romagna," built in 1910 at Ancona. Her engines were made by Messrs. Sulzer Brothers, of Winterthur. After running for a short time she was withdrawn from service, and was fitted with new or additional air compressors, and then resumed service. She, however, was lost at sea in November, 1911. It is believed that she is the only Diesel-engined vessel which has been so unfortunate.

The next vessel to be mentioned is the "Vulcanus," which was fitted with a single-screw, 6-cylinder, 4-stroke cycle engine of the "Werkspoor" type. Her cylinders are 15¾in. diam. with a stroke of 23⅝in. She commenced work in December, 1910, and was engaged on short runs in the North Sea until August, 1911, when she made a voyage to Genoa, returning to Amsterdam. She was then again employed in the North Sea until September, 1912, when she started on a Black Sea voyage. After two such voyages, in February, 1913, she sailed for Batoum: thence to Colombo, and she has since been running regularly between Singapore and the Dutch East Indian Islands. She has been frequently surveyed by Lloyd's Register, and the only troubles with her have been a burst air receiver and some ordinary defects which would occur in steam engines. Her engines have recently been surveyed, and after three years' working her cylinders have been rebored owing to their having worn slightly out of truth. There have been no difficulties with her owing to the Diesel principle, and, seeing that she was a pioneer, her success is remarkable.

The "Toiler" was built by Messrs. Swan & Hunter. She is a twin-screw vessel of 1,659 tons gross, and was fitted with single-screw Diesel engines with eight cylinders in all, 9⅞in. diam. by 14½in. stroke, made at Stockholm. After a short service in home waters she started in August, 1911, from the Tees for Halifax, and arrived there in September. She was the first Diesel-engined vessel to cross the Atlantic. She was afterwards employed on the Canadian Lakes. From the particulars stated it will be seen that she has exceptionally small power in proportion to her size, and the writer has been informed by her builders that, owing to her comparatively low speed, her engines will soon be taken out and replaced by steam engines of larger power.

The "Calgary" is a very similar vessel to the "Toiler," being approximately of the same tonnage. Her engines are of the same type but are more powerful, her cylinders being 11⅗in. diam. by 16$\frac{9}{10}$in. stroke. She was built in 1912, and is still trading on the Great Lakes and St. Lawrence River.

The next to be fitted with Diesel engines was the twin-screw vessel "Selandia," and, as she is a very large vessel engaged on long voyages, her performances have been watched with great interest. She commenced work in February, 1912, and has since traded regularly between Copenhagen and Bangkok, and is now on her sixth voyage. She has been regularly under survey by Lloyd's Register, but at no time on account of defects. On her first voyage she had two new pistons and two new cylinder liners fitted on account of some damage sustained through defective lubrication, and all her exhaust valves were then replaced by others of improved design. Any other work required to her has been such that steam engines would have needed. Altogether, especially as she was the first large Diesel-engined vessel of Messrs. Burmeister & Wain's, she has been remarkably successful.

The next vessel of Messrs. Burmeister & Wain was the "Christian X.," a duplicate of the "Selandia." She is owned by the Hamburg-Amerika Line. In July, 1912, she sailed for her first voyage to Mexico, then returned to Hamburg. She next made a voyage to Philadelphia and back without incident, sailed on her third voyage to Baltimore, met with a hurricane and had to return to Queenstown. During the heavy weather when she had to be slowed down the fuel valves became damaged. Owing to the oil used being of an easily ignitable character, the valve setting suitable for full power running with slower burning oil gave too much "lead" when running slowly, and caused the damage. After a very slight delay she resumed her voyage and has since been running regularly between New York and Brazil. In January last she met with her first serious trouble, the outer water jackets of some of her cylinders becoming cracked. The cause was attributed to scale forming on the inner liners, and thus permitting them to become overheated, their expansion cracking the outer jackets.

Other nearly similar vessels built by the same firm are the "Suecia," "Siam," "Annam," "Pedro Christopherson," "California," and "Fionia."

The "Suecia" is similar to, but rather smaller than, the "Selandia," and has the same arrangement of auxiliaries. She commenced work in December, 1912, trading between Stockholm and South America. On her second voyage she met with the accident to her air receiver already referred to in the paper. She has since been regularly at work, and is now on her fourth voyage, and no further troubles have been reported.

The "Siam" is also a similar vessel, but rather larger than the "Selandia." She commenced work in April, 1913. Her sister vessel, "Annam," commenced work in June, 1913. Both have continued steadily in service, and no incidents of any kind have been reported in either of these cases.

The "Pedro Christopherson" is sister to the "Suecia." She commenced work in August, 1913. Like her sister she is engaged in South American trade, and the only casualty which has been reported in her case was a collision with a quay wall.

The "California," whose engines are slightly larger than those of the "Selandia," commenced work in October last, and is engaged in the North Atlantic trade. No casualties of any kind have been reported in her case.

The "Fionia" is the vessel with the largest cylinders yet in use in any Diesel-engined vessel. She has twin-screw engines of a total of 4,000 i.h.p. There are six cylinders to each shaft, the diameter being 29in. and the stroke 43in. She had a very successful trial in December last, and on January 13th started on her first voyage. She returned to port next day with serious trouble to her air compressors, which were of different type to those previously used by Messrs. Burmeister & Wain. These have now been replaced by others of different design, and the vessel has again started on an Eastern voyage.

The "Jutlandia" is a sister vessel to the "Selandia," but was built and engined in this country by Messrs. Barclay, Curle, and Co. After a delay caused by a mishap, which occurred on a trial trip, to a part of the mechanism not connected with the Diesel cylinders, she started her first Eastern voyage from Copenhagen in August, 1912. She is now homeward bound on her fourth Eastern voyage. On the outward voyage, it is stated in the shipping papers that she collided with a floating derelict off Cape Finisterre, and damaged one of her shafts. Except for this accident, which has nothing to do with the Diesel principle, she has been remarkably successful.

All the foregoing vessels have 4-stroke cycle engines.

The next vessel to be referred to is the "Eavestone," which has 2-stroke cycle engines of the Carels type. She commenced work in July, 1912, made some short runs in the North Sea and Baltic, thence to Spain, and then crossed the North Atlantic. On her return she put into Fayal with machinery disabled, in January, 1913, and from the shipping papers it appears that new pistons and new cylinder covers had to be sent out to her to enable her to complete her voyage. She arrived in the Tees in March, and remained there, presumably under repair, till July 1st. During the remainder of last year she was regularly engaged between the United Kingdom and Baltic ports. Early this year she sailed for the Mediterranean, where she is at present at work.

In August, 1912, the "Monte Penedo" commenced work. Her engines are 2-stroke cycle, and were made by Messrs. Sulzer Bros. On her first voyage she arrived at Buenos Aires in October and remained there until the following January, when with new pistons which had been sent out to her, she made her

* Paper read at the spring meetings of the fifty-fifth session of the Institution of Naval Architects, April 2nd, 1914.

return voyage to Hamburg. She has since then been regularly at work on the United States and Brazilian coasts without any delays.

In November, 1912, the "Rolandseck" commenced work. Her engines were made by Messrs. Tecklenborg, and are of the 2-stroke Carels type. The papers show that she has since been running regularly between Portuguese ports and Hamburg, the only casualties reported being very slight, and to the hull only, no mention being made of the engines.

In the same month the "Juno" commenced work. She is an oil tanker, and is fitted with single-screw, 4-stroke engines of the "Werkspoor" type. Soon after starting she had a cylinder renewed. The defect which had occurred was attributed to locally deficient water circulation. This was remedied. She was first engaged on some short runs, but in January of last year she left Rotterdam for the East, where she has since been engaged running between the Dutch East Indies and Singapore with great regularity.

About the same time the "Emanuel Nobel" commenced work. She is also a tanker, but is fitted with twin-screw engines, each of which was a duplicate of those of the "Juno." Similar defects to those which had shown themselves in the "Juno's" cylinders were similarly remedied. Since then she has been kept constantly at work, and the only casualties reported are slight damages due to collision, and to heavy weather, and there is one record of her having put into port with overheated bearings.

The "Loudon" is a single-screw vessel fitted with sister engines to those in the "Juno." She commenced work in November of last year and has since been employed in regular work in the Dutch East Indies. The only casualty reported in her case was that she anchored at Dungeness on November 24th at 6-20, and signalled "defect," and proceeded at 8-23 the same evening.

Towards the end of 1912 the "Fordonian" was completed, and had a very successful trial. Her engines were made by the Clyde Shipbuilding and Engineering Company, of Port Glasgow, upon the Carels 2-stroke design, and were very similar to those of the "Eavestone." She started on a voyage to the Canadian Lakes, for service upon which she was intended. She returned to port through trouble with bilge pumps and with air compressor. These were remedied, but owing to the lateness of the season she was laid up at Greenock until May, 1913. During this time her cylinder covers, which were of cast steel, were renewed with others of cast iron, as the result of experience with other engines, not on account of developed faults. Nothing else was done to her engines, and in May she started a non-stop run to Quebec. She has since been running regularly and satisfactorily on the Canadian Lakes until the close of the season.

In May, 1913, the "Hagen," built by Messrs. Krupp, of Kiel, started on her first voyage. She is a twin-screw vessel, having six cylinders to each shaft. They are of the 2-stroke type. The two air compressors are worked by auxiliary oil engines, each being large enough to supply both engines. Her first voyage was to New York; on her return the air compressors gave much trouble, and she was more than three months under repair. One of her compressors was renewed at this time. She commenced her second voyage to New York in November last, and has now made two more voyages, during the last of which some of her pistons, both of the main and of the auxiliary engines, cracked. These pistons are cooled with fresh water. It was found that the circulation of the water had been partially obstructed through sediment from the water. The passages have now been enlarged to ensure a better circulation.

The "Loki" is a sister vessel to the "Hagen." She commenced work on October 30th, sailing between Hamburg and Philadelphia. She arrived back in December, when her engines were opened out for thorough examination, and sailed again in January for New York. It is reported in the papers that she remained in New York for 16 days repairing, and she is now on her homeward run to Hamburg.

The "Wotan" is the Diesel-engined vessel with the largest power on one shaft yet afloat. She has a single screw, there are six cylinders, each 23⅝in. diam. by 43in. stroke, working on the 2-stroke cycle. They were made by the Reiherstieg Company, of Hamburg, on the Carels 2-cycle plan, and indicate 2,300 h.p. After a successful prolonged trial she left Hamburg in September last for New York, and returned to Hamburg after the voyage without incident. On arrival her machinery, including the air compressors, was overhauled, and was all found in order. On attempting to start, trouble was experienced with the compressors, and the vessel was delayed for several days. She then started on a second voyage to New York, during which two crank-pin brasses gave trouble. As there was only one spare one on board this was fitted, and the vessel proceeded with five out of her six cylinders in action, and arrived at New York only a little late. Her return was without incident. On her third voyage outward she put into Plymouth, with the air compressor deranged, and was repaired there. After about three weeks' detention she again sailed on her present voyage.

The French barque "France" fitted with Carels type of engines has twin screws. Besides being of good mechanical power, she is rigged as a 5-masted barque and has full sail power. She started on her first voyage in November last, and has reached her destination in New Caledonia, and no casualties are reported.

The "Arthur von Gwynner" is fitted with 4-cylinder Junkers engine, not of the tandem type. She started service in November last, and so far her work has been satisfactory; no delays or casualties have been reported.

The "Sebastian" is the most recent Diesel-engined vessel to be put into service. She is twin screw, with engines made at Stockholm. She has just started on her first voyage, and has been reported as being "all well."

Mention ought to be made of the "Tynemount." She was fitted with two Diesel engines, made by Messrs. Mirrlees, Bickerton, & Day. Each engine drove an electric alternator, which was connected to a motor upon the screw shaft. The vessel and her machinery were described in a paper read at the Summer Meetings of this Institution in 1913.* So far the electrical portion of the equipment has not answered expectations. The difficulty, however, does not lie with the Diesel engines.

APPENDIX II.

CALCULATIONS OF TEMPERATURE, &c., IN DIESEL ENGINES.

Some particulars of carefully conducted trials of a 2-cylinder 4-stroke Diesel engine are recorded in "Engineering" of July and August, 1903. The following are some of the data recorded of a full power trial:—

Duration of trial	60 minutes.
Total revolutions	9,258.
Revolutions per minute	154·5.
Mean effective pressure......	113·4lbs. per square inch, left.
,, ,, ...	114·5lbs. per square inch, right
Indicated horse-power	101·0 left, 103·4 right.
Total oil used	67lbs.
Cooling water per minute ..	49·6lbs.
Change of temperature of water	52·5° C.
Temperature of exhaust	384° C.
Two cylinders, each diameter	400 mm.
,, ,, stroke ..	600 mm.

It is stated in the paper that the oil used on one of the trials had a composition—

Carbon	= 85	per cent.
Hydrogen	= 13·5	,,
Incombustible	= 1·5	,,

Two indicator diagrams are given; they are practically identical in the compression and expansion curves, and differ but slightly at the admission portion.

The swept volume of each cylinder is	2·663	cub. ft.
The clearance = ·08 of swept volume =	·213	,,
Total cylinder volume =	2·876	,,

One pound of air at atmospheric pressure (14·7lbs. per square inch) and at 32° Fah. occupies 12·384 cub. ft.

$$\text{At } 60^\circ \text{ Fah. it occupies } 12{\cdot}384 \times \frac{60 + 461}{32 + 461} = 13{\cdot}089 \text{ cub. ft.}$$

Assume that the pressure of air during the exhaust is 1lb. above the atmosphere, and that during the suction stroke it is 1lb. below atmosphere; also that the indrawn air is at 60° Fah.

* Trans. I.N.A., Vol. LV. (Part II.), p. 156.

The residual gas in the clearance at the end of the exhaust stroke will be at 15·7lbs. pressure; its volume will expand to

$$\cdot 213 \times \frac{15 \cdot 7}{13 \cdot 7} = \cdot 244 \text{ cub. ft.}$$

before the suction commences. This will leave

$$2 \cdot 876 - \cdot 244 = 2 \cdot 632 \text{ cub. ft.}$$

to be filled by the indrawn air. This is repeated every cycle, and this amount of air might be called the "cycle air."

The weight of the cycle air will be—

$$\frac{2 \cdot 632}{13 \cdot 089} \times \frac{13 \cdot 7}{14 \cdot 7} = \cdot 1874 \text{lb.}$$

of which 77 per cent. = ·1443lb. is nitrogen,
and 23 per cent. = ·0431lb. is oxygen.

In this particular case the blast air was taken from the main cylinder near the end of the compression and further compressed in a separate compressor. The same weight of air is, therefore, in the cylinder during the compression and the expansion strokes.

The weight of oil used per impulse stroke is—

$$\frac{67}{9258} = \cdot 007237 \text{lb.,}$$

of which 85 per cent. = ·006151lb. is carbon,
and 13·5 per cent. = ·000977lb. is hydrogen.

The carbon uses

$$\cdot 006151 \times \frac{32}{12} = \cdot 01640 \text{lb. of oxygen to burn it to } CO_2.$$

The hydrogen uses

$$\cdot 00097 \times \frac{16}{2} = \cdot 00782 \text{lb. of oxygen to burn it to } H_2O.$$

Total oil uses ·02422lb. of oxygen.

The final composition of the cycle air will, after combustion, be
·1443lb. of nitrogen.
·02255lb. of CO_2.
·00880lb. of H_2O.
and ·01888lb. of free oxygen.

The relative volumes of these when hot will be—

$$\frac{\cdot 1443}{28} = \cdot 005154 \text{ of N., or } 76 \cdot 4 \text{ per cent.}$$

$$\frac{\cdot 02255}{44} = \cdot 000513 \text{ of } CO_2\text{, or } 7 \cdot 6 \text{ per cent.}$$

$$\frac{\cdot 00880}{18} = \cdot 000489 \text{ of } H_2O\text{, or } 7 \cdot 2 \text{ per cent.}$$

$$\frac{\cdot 01888}{32} = \cdot 000590 \text{ of O, or } 8 \cdot 8 \text{ per cent.}$$

If the analysis be made cold and no allowance is made for the H_2O, which will then be water, the apparent volumes will be—

N = 82·4 per cent.
CO_2 = 8·2 ,,
O = 9·4 ,,

The analysis quoted in "Engineering" gives:—
N = 81·7 per cent. by diff.
CO_2 = 7·0 ,,
O = 11·3 ,,

$$\text{Actual air factor} = \frac{\text{Total Oxygen}}{\text{Consumed Oxygen}} = \frac{\cdot 02422}{\cdot 0431} = 1 \cdot 78.$$

It will be seen when dealing with temperatures that it is probable that the oil was not completely burned, as there must have been considerable combustion towards the end of the stroke, and quite possibly it was not absolutely complete at the end of stroke. It must be remembered that the exhaust may be smokeless, although part of the carbon may be only burned to CO, not to CO_2.

Next as to the relative volumes of the gas before and after combustion.

The law holds good that at the same temperatures and pressures the molecules of all gases have equal volume.

The molecule of carbonic anhydride is CO_2.
,, oxygen ,, O_2.
,, nitrogen ,, N_2.
,, H_2O gas ,, H_2O.

From this it is seen that CO_2 occupies the same volume as the oxygen used in its formation, but that H_2O gas occupies twice the volume of the oxygen which it contains.

The relative volumes of the gases before and after combustion when reduced to equal temperatures and pressures are—

Before combustion: $\frac{\cdot 1443}{28} = \cdot 005154$ of N.

$\frac{\cdot 0431}{32} = \cdot 001347$ of O.

Total ... ... = ·006501 of air.

After combustion: $\frac{\cdot 1443}{28} = \cdot 005154$ of N.

$\frac{\cdot 01888}{32} = \cdot 000590$ of free O.

$\frac{\cdot 02256}{44}$ or $\frac{\cdot 01640}{32} = \cdot 000512$ of CO_2.

$\frac{\cdot 00880}{18} = \cdot 000489$ of H_2O.

Total .... = ·006745.

Hence, after combustion, if the temperatures and pressures of the gas are reduced to the same standard, the volume is increased in the ratio of

$$\frac{\cdot 006745}{\cdot 006501} = 1 \cdot 038, \text{ say, 4 per cent. increase.}$$

the increase being due to the combustion of the hydrogen of the oil.

Although the total increase does not take place until the whole of the hydrogen has been burnt, it is probable that the hydrogen does burn more promptly than all the carbon, so that most of the increase of volume will take place comparatively early in the stroke. In the calculations the increase of volume of 4 per cent. is assumed throughout the whole of the impulse stroke.

Temperature of Exhaust.—The exhaust opens shortly before the end of stroke, and, therefore, slightly less work is done by the gas than would occur if the expansion continued till the end of the stroke, and the exhaust will accordingly be slightly hotter. It will be assumed, however, that the expansion is continued to the end of the stroke, in which case the terminal pressure will be 51lbs. per square inch. On the release the gas must expand to atmospheric pressure (14·7lbs. per square inch). To do so it must displace a certain volume of the atmosphere. Let V be the volume in cubic feet to which the gas expands, then the volume of atmosphere displaced to make room for it is V−2·876 cub. ft. In displacing this atmosphere the work done is (V − 2·876) × 14·7 × 144 ft.-lbs.

This is equivalent to—

$$(V - 2 \cdot 876) \times \frac{14 \cdot 7 \times 144}{778} = (V - 2 \cdot 876) \times 2 \cdot 72 \text{ B.T.U.}$$

If the gas expanded into a vacuum so that no work was done by its expansion, its temperature would not fall, but as it does work during its expansion its temperature correspondingly falls.

The weight of gas expanded is—

$$1 \cdot 08 \times (\cdot 1874 + \cdot 007237) = \cdot 2102 \text{lbs.}$$

The specific heat at constant pressure is ·25, hence the fall of temperature due to the work done during the expansion is—

$$\frac{2 \cdot 72}{\cdot 2102 \times \cdot 25} \times (V - 2 \cdot 876) = (V - 2 \cdot 876) \times 51 \cdot 76° \text{ Fah.}$$

If we assume the temperature of the gas before expansion is 2,000° Absolute, since P × V = C × T, we get—

$$51 \times 2 \cdot 876 = C \times 2{,}000° \text{ before expansion, whence } C = \cdot 073338.$$

After expansion, if T is the final temperature Absolute—

$$\begin{aligned} 14 \cdot 7 \times V &= C \times T. \\ &= \cdot 073338 \{ (2000 - 51 \cdot 76 (V - 2 \cdot 876) \} \\ &= \cdot 073338 (2148 \cdot 9 - 51 \cdot 76 V). \\ &= 157 \cdot 6 - 3 \cdot 796 V. \\ V &= 8 \cdot 521 \text{ cub. ft.} \end{aligned}$$

and fall of temperature = (8·521 − 2·876) × 51·76
= 292° Fah.

Exhaust temperature = (2,000 − 292) = 1,708° Abs. = 1,247° Fah.

To ascertain the effect which an error in the estimation of the cylinder gas temperature would make in the calculation of the

fall of temperature, assume the temperature to be 2,100° instead of 2,000°, the following would be the calculation :—

$$51 \times 2\cdot876 = C \times 2100. \quad C = \cdot069846.$$
$$11\cdot7\ V = \cdot069846\ \{2100 - 51\cdot76\ (V - 2\cdot876)\}$$
$$= \cdot069846 \times (2248\cdot9 - 51\cdot76\ V).$$
$$157\cdot0 = 3\cdot614\ V$$
$$V = 8\cdot576 \text{ cub. ft.}$$

and fall of temperature $= (8\cdot576 - 2\cdot876) \times 51\cdot76 = 295°$ Fah.

That is, an increase of 100° in the absolute temperature increases the fall by 3° only.

Temperature in the Cylinder.—Before commencing to calculate the temperature of the gas at various parts of the cycle, we want to know what it is at any one definite point. The most convenient starting point is the commencement of the compression. At this point we have a pressure of 13 7lbs. per square inch at a total volume of 2·876 cub. ft.

If T be the temperature of the exhaust when the clearance is filled with it at a pressure of 15·7lbs., we have the heat in this represented by ·213 × 15·7 × T. This expands to a volume

$$\cdot213 \times \frac{15\cdot7}{13\cdot7} = \cdot244 \text{ cub. ft.}$$

before the new air begins to enter, and we have then (2·876 − ·244) cub. ft. drawn in at 60°. This would give a mean temperature of

$$\frac{\cdot213 \times 15\cdot7 \times T + 2\cdot632 \times 13\cdot7 \times 60}{2\cdot876 \times 1\cdot37} = \cdot0849\ T + 54\cdot9° \text{ Fah.}$$

To this must be added the temperature which the indrawn air derives from the hot cylinder during the suction stroke, which, however, cannot be so much as the heat lost during the exhaust stroke.

In making the calculation, 100° Fah. has been taken as the temperature at the commencement of compression ; the following temperatures are then obtained at the various piston positions.

In order to obtain the mean temperatures on a basis of time, the piston positions are taken for every 10° of the crank positions. The length of connecting rod is assumed to be 4 cranks.

For the compression stroke we have P.V = C T (absolute temperature).

$$13\cdot7 \times 1\cdot08 = C \times 561,$$

whence—

$$\frac{1}{C} = 3\cdot79 \text{ and } T = \text{Pressure} \times \text{Volume} \times 37\cdot9.$$

For the impulse stroke—

$$T = \text{Pressure} \times \frac{\text{Volume}}{1\cdot04} \times 37\cdot9 = \text{Pressure} \times \text{Volume} \times 36\cdot4.$$

From these we obtain the values shown in the following table :

Angle of Crank.	Swept Space.	Total Space.	Compression. Pressure from Diagram.	Compression. Temperature Absolute.	Compression Temperature Fahrenheit.	Impulse. Pressure from Diagram.	Impulse. Temperature Absolute.	Impulse. Temperature Fahrenheit.
			lbs.			lbs.		
0	0	·08	490	1,483	1,022	490	1,483	1,022
10	·0095	·0895	415	1,405	944	550	1,795	1,334
20	·0375	·1175	302	1,345	884	615	2,635	2,174
30	·0827	·1627	215	1,325	864	502	2,970	2,509
40	·1430	·2230	138	1,165	704	365	2,965	2,504
50	·2157	·2957	90	1,010	549	255	2,745	2,284
60	·2974	·3774	62·5	894	433	185	2,545	2,084
70	·3831	·4631	46	807	346	145	2,450	1,989
80	·4747	·5547	35	736	275	115	2,330	1,869
90	·5631	·6431	28	682	221	95	2,225	1,764
100	·6484	·7284	23	635	174	80	2,125	1,664
110	·7251	·8051	20	611	150	70	2,055	1,594
120	·7975	·8775	18	599	138	62·5	2,000	1,539
130	·8585	·9385	17	605	144	60	2,045	1,584
140	·9090	·9890	16	600	139	57·5	2,070	1,609
150	·9487	1·029	15·5	603	142		Exhausting.	
160	·9771	1·057	15	601	140		..	
170	·9942	1·074	14	570	109		..	
180	1·00	1·080	13·7	561	100		..	

Note. If the expansion had been carried to the end of the stroke before exhaust, the pressure would be 51lbs. per square inch and the temperature 2,010° Absolute = 1,549° Fah. It will be seen that the temperature is rising before the exhaust takes place, notwithstanding that work is still being done by the expanding gas. This shows that combustion is still proceeding, and points to the conclusion that it is not entirely completed before the exhaust takes place.

Mean Temperature in Cylinder. During compression, the mean temperature shown in the table is 403° Fah. If during the latter portion of the stroke, whilst the gas is being exhausted, we take the temperature as a mean between 1,609° Fah., which is the temperature just before the opening to exhaust, and 1,549° Fah., which would be the temperature if the expansion was carried to the end of the stroke, the mean temperature during the impulse stroke of the cycle will be 1,823° Fah. During the exhaust stroke the piston is expelling the hot gas, whose temperature has fallen to 1,257° Fah., by expanding down to atmospheric pressure. This may be taken as the temperature during this stroke. During the suction stroke the temperature may be taken as 100° Fah. The mean of these four cycles is 896° Fah. If we have the same diagram in a 2-cycle engine for comparison, we have a mean temperature

$$= \frac{1823 + 403}{2}$$
$$= 1{,}113° \text{ Fah.}$$

which is 217° above the mean temperature in the 4-cycle cylinder.

In an ordinary Diesel engine as now made, the air used for the injection of the fuel is supplied separately, and is, therefore, not in the cylinder during the compression part of the diagram. As it is in the cylinder during the impulse stroke, it must be taken account of in dealing with the expansion part of the diagram. It is usually considered that the air used for injection is 6 litres per brake horse-power per minute, measured at atmospheric pressure : this is about 6·2 per cent. of the swept volume. In estimating the temperatures during the impulse, this must be allowed for in addition to the 3·8 per cent. of volume due to the combustion of the hydrogen of the oil, so that a total augmentation of 6·2 + 3·8 = 10 per cent. has to be allowed for in the calculations. The following are the calculations from the diagram of the "Suecia's" engines :—

Angle of Crank.	Total Space.	Compression. Pressure by Diagram.	Compression. Temperature. Absolute.	Compression. Temperature Fahrenheit.	Impulse. Pressure by Diagram.	Impulse. Temperature Absolute.	Impulse. Temperature Fahrenheit.
0	·08	487	1,475	1,014	487	1,475	1,014
10	·0895	460	1,558	1,097	503	1,550	1,089
20	·1175	335	1,490	1,029	514	2,080	1,619
30	·1627	225	1,385	924	506	2,830	2,369
40	·2230	150	1,268	807	368	2,830	2,369
50	·2957	98	1,090	629	256	2,605	2,184
60	·3774	67	957	496	183	2,380	1,919
70	·4631	47·5	834	373	132	2,110	1,649
80	·5547	34	715	254	101	1,932	1,471
90	·6431	25·5	622	161	81	1,792	1,331
100	·7284	20·5	566	105	67·5	1,690	1,229
110	·8051	17·5	535	71	58	1,610	1,149
120	·8775	16	533	69	51	1,540	1,079
130	·9385	15	533	69	46	1,485	1,024
140	·9890	—	-	—	44	1,518	1,057
150	1·029	—	-	—	42·5	1,505	1,044
160	1·057	—	—	—	40·5	1,475	1,014
170	1·074	—	—	—		Exhausting.	
180	1·080	13·7	561	100		..	

Mean pressure, 6·19 kg. per square cm. = 88lbs. per square inch.

Mean impulse temperature	=	1423° Fah.
,, compression	=	417° ,,
,, exhaust	=	735° ,,
,, suction	=	100° ,,
		664° Mean.

Petrol Electric Rail Motor-car.—Some exhaustive trials have recently been made in Southern Sweden with a rail motor-car equipped with a Diesel engine and electric motor. The trials, which covered a distance of over 2,000 miles, proved satisfactory in every respect. The engine weighs 33 tons, and was run at a speed of 34 miles per hour on level track. The average consumption of fuel—a crude oil from Swedish shales—amounted to about 9lbs. per mile. With 110 passengers the car attained a speed of 31 miles.

ELECTRIC FURNACES FOR STEEL MAKING.*

BY E. B. CLARK.

THE intending user of an electric furnace wishes dependable answers to two questions: (1) How will an electric furnace compare with some other apparatus for producing or refining steel as to quality of output and cost of operation? (2) Assuming the wisdom of an electric furnace installation, what is the best type of furnace, and what size of unit is proper?

Most of the available literature upon these subjects is of a theoretical nature. Information from a practical standpoint will generally be acceptable, but when one is actually a user of electric furnaces in the commercial production of steel he does not find a great deal to say. After all, this is not a surprising fact, for the electric furnace does not offer anything radically new in the production or refining of steel. Its use is generally contemplated for a purpose where steel may be made or refined either in an electric furnace, a crucible furnace, a Bessemer converter, or an open-hearth furnace.

The crucible furnace enables one to make accurate alloy mixtures of high quality without contamination from gases or furnace linings. Practically no refining can be done, and therefore high-grade materials must be used for the mixture. By the law of supply and demand, the price of pure materials for use in crucible furnaces will be higher where the crucible process is employed to a considerable extent. The electric furnace will produce steel of the same degree of purity as a crucible furnace, and the possibility of refining in an electric furnace makes possible the use of less pure materials. This is an advantage for the electric furnace, and, at the same time, an advantage for the crucible furnace, because the demand for the high-grade materials necessary in the crucible process is reduced by each additional electric furnace installation, and therefore the price of the charge for the crucible furnace is reduced. This is especially true as applied to the small crucible furnaces used in foundry practice, which require low-phosphorus steel punchings for their successful operation.

The small Bessemer converter, or Tropenas vessel, is capable of producing hot steel in small units quickly. It does not permit of refining, however, and, therefore, necessitates the use of low phosphorus and low sulphur pig iron, which must be pre-melted in a cupola using high-grade coke. The losses are severe and the steel is not free from oxides and occluded gases. The electric furnace will produce steel just as hot as the small Bessemer vessel, but free from oxides and occluded gases. However, the electric furnace requires scrap for charging rather than pig iron, so if only pig iron is available at commercially desirable figures, the pig must be converted into steel before charging into the electric furnace.

The open-hearth furnace will produce from pig and scrap, steel of a fairly high degree of purity and of fairly high temperature. The electric furnace will do the same thing (except that the use of a large percentage of pig is not desirable), and is capable of producing purer and hotter steel than is the open-hearth under usual operating conditions.

Summarising these general observations, it may be said that for the alloying of steels the electric furnace offers nothing that the crucible furnace does not; for the production of very hot steel the electric furnace offers nothing that the Bessemer converter does not; and, metallurgically speaking, the electric furnace offers nothing that the open-hearth does not. It is a fact, however, and this is the important fact, that the electric furnace combines in itself certain advantages of all three of the other processes mentioned. On the other hand, it is seldom that one wishes to secure the advantages of all these other three processes combined in one. Generally, a certain object is in view by the intending user of an electric furnace or some other form of apparatus for producing steel. Of course, broad generalities will not solve this problem. The cost of production is the final answer from a commercial standpoint, and this depends not only upon the market for the intended output, but upon the available supply of steel-making materials, and upon the availability of a satisfactory and sufficiently cheap source of electric power. In passing it might be observed that this question of electric power supply is generally not so serious as might at first appear. In the first place, there are many locations where a sufficient amount of fairly cheap electric power may be purchased; and, in the second place, the item of power is not often of supreme importance.

There are other elements entering into the production of electrically refined steel which have a far greater influence on the cost of production than is generally credited. The most important of these is experience. It should be understood clearly that the electric furnace is a more delicate apparatus than any of the other three furnaces mentioned. It is more difficult to handle, and its operation offers more likelihood of mishaps. Electric-furnace operation has not yet been reduced to standard practice. Melters familiar with its operation are scarce and difficult to find.

To attempt an answer as to what type of furnace is best is as unsatisfactory as to make general comparisons between electric furnaces and other furnaces. If we could accept at face value the statements of a number of men interested in the development of certain electric furnaces, we could easily believe that as soon as a foundryman had installed an electric furnace (provided he installed the right one) his troubles would be at an end. As a matter of fact, he is apt to find that they are just beginning. In the first place, unless the design of the furnace has been thoroughly tried out in practice, it will certainly have to be modified considerably from the designer's ideas. In the second place, the user will certainly find the furnace to be a more delicate piece of apparatus than he had anticipated. He will find that while he can make steel of a very high quality, he can also make, without difficulty, much steel of a very low quality. If there are in the society some men who have been using electric furnaces for the production of castings or special steels, they will have no difficulty in recognising these remarks as coming from one who has had such experience.

It so happens that the speaker's experience has embraced not only a study in this country and Europe of the design and operation of a number of different types of furnaces, but has embraced the actual operation of two typical types of furnaces for the production of steel castings. The investigation as to which general type of furnace is best led in my case, as in that of most others, to much confusion of ideas. It is so evident that each type has certain advantages and disadvantages, and so impossible accurately to gauge the proper importance of the various advantages and disadvantages, that one cannot reach a conclusion as to which type of furnace is best with confidence in his conclusion. Perhaps the only way to learn is to try them all. As a matter of fact, the speaker has already tried two, and feels that he has not yet decided the question.

We have operated two furnaces of one to $1\frac{1}{2}$ tons capacity each, of the surface-arc type. This general type is best exemplified by the Stassano furnace, the general construction of which is well known. Our furnaces use 3-phase power, and the arcs are maintained above the surface of the bath. They are lined with magnesite brick, which, of course, while a high refractory, is quite susceptible to damage by sudden heat changes. Very hot and very good steel has been produced in these furnaces, the cost of repairs has been rather high, due to necessity for relining rather frequently. We have found that linings last, under proper treatment, about 40 to 50 heats, though we feel that some changes in methods of construction would increase the number of heats per lining and, therefore, decrease this item of cost very considerably.

The labour cost on operating these furnaces has been found to be rather high, but this is principally due to the small capacity of the furnace. The power costs have not been high when the furnace has been operated continuously, even despite the small capacity of the charge. Where commercial conditions have made it necessary to permit considerable time to intervene between heats, the power consumption has been increased, due to the necessity of keeping the furnace fairly hot between heats. Experience in operation, however, has made it possible to reduce this item of expense far below

* Abstract of paper read before the American Electro-chemical Society, April 16th, 1914.

what was originally believed possible. Even where the furnace is operated on day turn only, and kept hot over night with current, the power consumption was surprisingly low for so small a furnace. Electrode costs have been quite reasonable.

Summing up, it may be stated that the operation of these furnaces has been quite satisfactory, as regards quality of output, reliability of operation, and cost of production, when the size of the furnace is taken into consideration. Two furnaces should be used alternately, so that ample time can be allowed for relining, without interfering with the continuous supply of hot metal.

The increasing demand for hot metal for foundry purposes led us to consider the installation of additional metal-producing capacity. We consider that the type of furnace which has just been described is not suitable for units above from 2 to $2\frac{1}{2}$ tons capacity, because of the increasing difficulty which probably would be experienced with linings in the larger sizes. As a furnace of approximately five tons capacity was necessary, we decided to install one of the submerged-arc type, represented by such furnaces as the Heroult and Girod. A Heroult furnace was put in, and has been operated very satisfactorily. Power consumption has been less than in the smaller furnaces, but only by an amount which would be expected for the difference in the size of the furnaces.

As a matter of fact, claims for low power consumption by any furnace should be received sceptically. It is a fact that the power consumption of any electric furnace depends somewhat upon the efficiency of the furnace, but it also depends to a far greater extent upon the method of operating the furnace. The furnace efficiency depends upon the thoroughness of the heat insulation, for, after all, the only heat which is lost is that which escapes by radiation or conduction. That which goes out in the slag, or in the steel, depends not upon the efficiency of the furnace, but upon its mode of operation. Where a high degree of refining is necessary, slags must be taken off, at the cost of power consumption. Where the furnace must be operated with considerable time between the heats, heat is escaping rapidly during that idle time.

Where heats must be held in a furnace, or melted slowly, to meet a definite schedule, a high power consumption must be expected. For these reasons it appears that the claims for low power consumption of certain furnaces are practically valueless from an operating standpoint. The conditions of operation, rather than the type of furnace, are what control the power consumption, though, of course, the construction of the furnace, as regards heat insulation, does have some influence.

In our 5-ton Heroult furnace, we have found the cost of repairs to be lower than in the smaller furnaces. This is due to a considerable extent to the type of furnace, but our experience in the operation of electric furnaces has also helped in this respect. Furthermore, we have not yet reached our hoped-for results as to repairs. The labour costs are less on the larger furnace, as might be expected, partly because it is automatically controlled, and largely because of its increased output.

To summarise our views upon the relative merits of the two types of furnaces, as based upon our own experience, I would say that we have found the surface-arc type to be a much better furnace than its critics would have one believe. On the other hand, we have found the submerged-arc type better for our purposes because of its larger capacity and lower cost of operation. It would not be fair, however, to ascribe the lower costs entirely to its type, for the capacity of a unit certainly has much to do with the lower cost. Where a foundry is, like ours, entirely dependent for its supply of hot metal upon the electric furnace, this type is better by reason of less necessity for lining repairs.

No attempt has been made here to give actual figures of operation. This is not due entirely to reluctance to publish our costs of production. As a matter of fact, the costs of production are so much dependent upon local conditions, such as quality of scrap available, continuity of operation, and price of electric power, that results obtained in one installation, if used as a basis for other installations, may be most misleading. The predominating influences in this case are the commercial conditions surrounding each separate installation.

In conclusion, I wish to reiterate my statement that an intending user of an electric furnace may expect to learn much more about the furnace by his experience after he gets it than by the statements of some one who wishes to sell him a furnace.

IMPROVEMENTS IN FLEXIBLE COUPLINGS.

A METHOD of securing the leather or other flexible connections to the discs of flexible couplings, the invention of Messrs. Croft and Perkins, Great Northern Works, Leeds Road, Bradford, is shown in the accompanying cuts. Hitherto it has been common practice to arrange projections on both the faces where the leather or other material is secured thereto, and secure it to these projections by means of pins or bolts, which are used to press washers firmly on to the material to hold same in position. The faces of these projections have hitherto been flat. Messrs. Croft & Perkins have found that by forming these projections with dished or curved surfaces or with recessed or convex surfaces and forming the nut or washer which is held on the other side of the leather so that

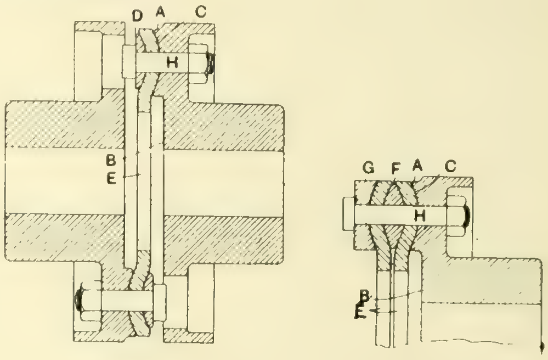


FIG. 1. FIG. 2.
IMPROVEMENTS IN FLEXIBLE COUPLINGS.

its face has the reverse contour to that given to the face of the projection, a very much better hold is obtained on the leather and its life accordingly prolonged. As shown in the illustrations, the projections A on the faces B of the two discs are dished or formed concave as at C, while the adjacent surface of the washer D is formed correspondingly convex. On the other hand, the face of the projection A may be formed convex and the adjacent face of the washer made concave. In the arrangement shown in Fig. 2 the leathers E are made multiple or divided, in which case the face of the projection A is formed concave, while the intermediate washer F which comes between the two pieces E of leather is formed with the face adjacent to the projection convex and with its other face also formed convex, while an additional washer G with a concave face is placed on the bolt H on the far side of the second piece or length E of leather.

CORROSION OF METALS AND ALLOYS IN CONTACT.

IN the "Engineering Record" for January 24th last, Richard H. Gaines, chemist, Board of Water Supply, New York City, gives the results of experiments made during the past two years at the laboratory of the New York Board of Water Supply to determine the loss suffered from corrosion by steel and other metals when in contact under different conditions, and incidentally to observe some of the phenomena of galvanic action.

In the first series of experiments specimens of the metals listed in Table I. were weighed and embedded singly and in contact in damp concrete and allowed to remain therein for two months. At the end of the test period the concrete blocks were broken up and the metals taken out, carefully cleaned, dried, and re-weighed, the loss in weight representing the amount of corrosive action in each specimen. The resulting losses show but slight differences when in contact and alone, and, therefore, give no positive evidence of electrolytic action when the metals are coupled in concrete. With the exception of the lead the corrosion loss of all the metals was negligible, that of the Monel metal almost nil. The corrosive action in

the case of lead is purely solvent in character, due to the alkali, and no surface coating is formed to hinder progressive deterioration. The metal specimens all presented about the same appearance when taken out of the concrete as when put in.

TABLE I.—*Corrosion in Concrete.*

Metals	Jan. 2, 1912	Mar. 4, 1912	Grams loss, 2 mo.	Loss in grams, per sq. ft.
SINGLE METALS.				
Manganese bronze	73·6655	73·6475	0·0180	0·32
Steel	39·1556	39·1481	0·0075	0·135
Lead	92·3806	91·7146	0·6660	11·99
Copper	73·7630	73·7272	0·0358	0·64
Monel metal	62·9667	62·9646	0·0021	0·04
METALS IN CONTACT.				
1—Steel	37·0380	37·0270	0·0110	0·20
1—Manganese bronze	70·6864	70·6700	0·0164	0·30
2—Steel	38·1746	38·1700	0·0046	0·08
2—Lead	90·0399	89·5408	0·4991	9·08
3—Steel	38·8055	38·8031	0·0014	0·03
3—Copper	70·1913	70·1348	0·0565	1·04
4—Steel	38·6396	38·6271	0·0125	0·23
4—Monel metal	60·1092	60·1074	0·0018	0·30
5—Steel	34·5625	34·4626	0·0999	2·48
5—Lead	83·8596	83·5163	0·3433	6·77
5—Copper	68·9752	68·9626	0·0126	0·31
6—Steel	34·7072	34·8026	0·0676	1·68
6—Fibre	—	—	—	—
6—Copper	64·1247	64·1122	0·0125	0·31

After the first series of tests was completed the same specimens, singly and in contact, were placed in Mason fruit jars freshly filled with Croton water. The jars were then sealed and put on a shelf in the laboratory, where they remained about 19 months. At the end of this period the specimens were taken out of the jars and carefully cleaned, dried, and re-weighed. The losses due to corrosive action are given in Table II. In each of the foregoing series of experiments (*i.e.*, in damp concrete and in Croton water) specimens numbered 1, 2, 3, and 4 were in absolute metallic contact, flatly bolted together by iron machine screws and nuts. Specimen 5 consisted of three metals flatly bolted together, but the connecting bolts were insulated from the plates by fibre collars and washers. Specimen 6 was made up of two metals separated absolutely from galvanic contact by a fibre plate, but held together by bolts which were also insulated from the plates by fibre collars and washers.

TABLE II.—*Corrosion in Water.*

Metals	Mar. 4, 1912	Oct. 3, 1913	Loss or gain, grams, 19 mo.	Loss, grams, per sq. ft.
SINGLE METALS.				
Manganese bronze	73·6475	73·6971	+0·0496	—
Steel	39·1481	36·9767	−2·1714	39·08
Lead	91·7146	91·7591	+0·0445	—
Copper	73·7272	73·7254	−0·0018	0·032
Monel metal	62·9646	62·9554	−0·0092	0·17
METALS IN CONTACT.				
1—Steel	37·0270	35·7425	−1·2845	23·12
1—Manganese bronze	70·6700	70·6822	+0·0122	—
2—Steel	38·1700	36·9922	−1·1778	21·20
2—Lead	89·5408	89·3314	−0·2094	3·77
3—Steel	38·8031	37·6435	−1·1596	20·87
3—Copper	70·1348	70·1522	+0·0174	—
4—Steel	38·6271	37·7372	−0·8899	16·02
4—Monel metal	60·1074	60·1108	+0·0034	—
5—Steel	34·4626	33·2073	−1·2553	22·59
5—Lead	83·5163	83·4896	−0·0267	0·48
5—Copper	68·9626	68·9684	+0·0058	
6—Steel	34·8026	34·4543	−0·3483	6·27
6—Fibre	—	—	—	—
6—Copper	64·1122	64·1047	−0·0075	0·14

The evidence from these experiments apparently indicates, however, that contact between steel and bronze, and steel and the other metals of the series, neither promotes nor accelerates the corrosion that normally takes place in steel alone. By its very lack of homogeneity in composition and structure the average steel surface in water as it occurs in nature presents all the conditions necessary for active electro-chemical corrosion. What the writer once termed auto-electrolysis is the inevitable outcome, and this process in steel does not appear to be hastened by contact with other metals or alloys. In fact, the legitimate conclusion from the foregoing experiments is that rather less than more galvanic action arises from contact between steel and the other metals of the series than from contact between steel and steel. In actual practice it has been found that if a steel nut is put on a steel bolt and subjected to corrosive conditions, in a comparatively short time the steel nut will have to be hammered or split off, if gotten off at all, on account of rusting together from local corrosive action; whereas a brass or bronze nut on a steel bolt under similar condition can be readily screwed off. This is a very important consideration where quick changes in waterworks machinery or installation must of necessity be made from time to time.

INDUSTRIAL AND TRADE NOTES.

Clyde Shipbuilding.—During April the tonnage launched from Clyde shipbuilding yards was satisfactory. There were launched on the river 34 vessels of 58,000 tons, as compared with 16 vessels of 24,631 tons in the previous month, and 27 vessels of 119,303 tons in April of last year. The Clyde total for the four months consists of 82 vessels of 153,985 tons, as compared with 68 vessels of 237,161 tons at the same period of last year.

Proposal to Adopt the Calorific Test for Gas.—The London Gas Light and Coke Company's Bill which was before a Select Committee of the House of Lords on the 28th ult., has for its object to abolish the illuminating power test for gas, and substitute exclusively the calorific (or heating) test. Mr. H. Lloyd, K.C., for the promoters, said the circumstances under which gas was used had in recent years undergone great changes. Nowadays gas was used in almost all cases with an incandescent burner which required heat to render the mantle incandescent. The other reason for the proposed change was the great development in the supply of gas for heating, cooking, and power. Hitherto illuminating power had been the standard test of gas, but as the result of these changes illuminating power was not the essential feature of gas, but heating power. The illuminating power test was a theoretical test, and the results of these tests were largely dependent upon human ability and agency. The calorific test largely eliminated the personal element, and the test was quick and simple.

Motor Boats for the "Aquitania."—Messrs. John I. Thornycroft and Co., Ltd., have recently completed two motor boats which will be carried by the new Cunard steamship, "Aquitania." The dimensions of the new boats are: Length, 30ft.; breadth, 9ft. 6in.; depth, 4ft. 6in. Each boat is fitted with a Thornycroft paraffin motor developing 30 b.h.p. These motors are arranged to start on petrol until the vaporiser is sufficiently heated, and then turned over to paraffin. The design is a distinct departure from the usual type of ship's boat, its primary function being to tow away the ordinary rowing lifeboats from the scene of a disaster. Each of the two boats carried would be able to tow a considerable number of boats. The wide beam and specially designed lines make them excellent sea boats. An important feature with this type of craft is the wireless installation, by means of which the boats can be kept in touch with other vessels in the line of shipping. The receiving range for these sets are about 300 miles. One of the boats has recently been through her official trials with satisfactory results, the speed obtained being nine miles per hour.

New Mining Law in China.—H.M. Minister at Peking has forwarded to the Board of Trade a translation of the new mining law which was published by the Chinese Government in the Official Gazette of March 11th. Article 4 of the new law provides that subjects of treaty nations may secure mining rights when doing joint business with Chinese subjects, but they must not hold more than half of the total number of shares in the concern. Such foreigners must also present to the Minister of Agriculture and Commerce, or to the Director of Mining Supervision Office, a certificate issued by their own diplomatic officer or consul proving that they are willing to be subject to these regulations and other laws connected with them. The exploitation of salt and petroleum is reserved to the Chinese Government. Article 111 provides that contracts and agreements for the raising of foreign capital for the development of mines, made before the present regulations became operative, shall continue in force as heretofore. A translation of the new law, which came into force on March 11th, may be consulted by firms interested at the Commercial Intelligence Branch of the Board of Trade, 73, Basinghall Street, London, E.C.

Royal Commission on Railways: Difficulties of State Ownership.—At a meeting of the Royal Commission on Railways, on April 30th

Mr. William C. Thorne, solicitor to the Mersey Docks and Harbour Board, gave evidence on behalf of dock undertakings representing a total capital of upwards of £106,000,000. In their view the success of the principal non railway owned ports—for example, Liverpool and Glasgow—had largely been brought about by the fact that they had been managed by shipowners, merchants, and traders engaged in the trade of the place and knowing the requirements of trade. For these reasons they were convinced that the best form of management of port and dock undertakings was management by those directly interested in the successful development of the business of each individual port and responsible for the finance of their undertakings. If a proposal were made to split up the present composite undertakings of the railway companies in order that the State should conduct only the purely railway business, it would be necessary to consider what could be done with the port or dock undertakings which were at present owned by railway companies, and were in competition with such undertakings as the independent port and harbour trusts. That in itself was a big problem. It would, in their opinion, be difficult now to establish independent companies or public trusts under the control of traders and shipowners and railway owned ports, and in any event the process of establishing them would be a long one, and trade at the port would suffer in the operation. They therefore doubted at present the practicability of reversing to-day the policy of recent years by separating from the railway undertakings those dock and harbour undertakings which had, in fact, become combined with railways into one system or business. The other alternative would be that State ownership should include the railway docks and harbours, but a State Department would lack the insight which shipowners, merchants, and traders gained from the conduct of their own businesses. At the same time State control or ownership of one group of ports connected with State owned railways would adversely affect the rival and independent ports. It was not to be supposed that the Board of Trade would retain complete independence of mind after the nationalisation of railways. There seemed to be so many new difficulties and dangers to commerce involved in State ownership that they thought it would be wiser to see whether existing difficulties could not be adjusted or surmounted by less drastic action before taking a step so fateful and so completely beyond recall.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1913.

Manufacture of steel. Viscount Chetwynd. 1306.
Delivery valve or inlet valve for air compressors. Mould. 6450.
Packing for piston rods. Allen. 8470.
Glands for stuffing boxes. Payne. 8488.
Vertical retorts for use in the manufacture of gas. Drakes, Ltd., and Dobson. 8524.
Starting and igniting systems for the engines of motor vehicles. Varley. 8679.
Device for cleaning cylinders and facilitating starting of internal-combustion engines. Hendricks. 8826.
Manufacture of wire. Girdwood. 8912.
Apparatus for converting reciprocatory movement into rotary motion. Wellisch & Heller. 8948.
Belt, rope, or chain gearing. Hodgkinson. 8983.
Valve mechanism of internal combustion engines. Simpson. 9073.
Draught gear for railway vehicles. Willison. 9081.
Valves for steam engines. Adams & Leach. 9124.
Clutches. Atkins. 9289.
Gear-cutting machines. Parsons, Carnegie, & Cook. 9483.
Steam generator tube stopping means. Houston. 10136.
Regenerative coke ovens. Lecocq. 10253.
Clutches. Joseph Cook, Sons, & Co., and Pluse. 10577.
Valve springs for internal combustion engines. Rudge Whitworth, Ltd., and Whitmill. 10626.
Internal combustion engines. Pieper. 14590.
Indicators for steam engines. Korosy. 15339.
Plugs for boiler tubes. Mason. 16545.
Liquid meters. Kent. 17175.
Variable speed transmission gear for self propelled vehicles. Richardson. 17507.
Means for actuating mechanical stokers for boiler furnaces. Petersen. 17525.
Carburetters for internal combustion engines. Greiner. 17962.
Machinery for the manufacture of tin terne and like coated metal plates. Richard Thomas & Co., and Lewis. 18783.
Rotary mechanisms for the transmission of power at variable speeds. Hunt. 19904.
Boiler tube cleaners. Thompson. 20277.
Shaft couplings. Soc. Anon. des Automobiles Unic. 22526.
Tachometers. Hoeft. 23639.
Process of heating electrical furnaces. Soc. Generale des Nitrures. 24347.
Railway rail joints. Reinhart. 24921.
Two stroke cycle explosion engines and air compressors and exhausters. Hardy. 25683.
Apparatus for measuring the velocity of flow of gases and vapours. Morris. 25923.
Two stage compression pumps for air, gas, or like fluids. Hill and Hill. 26861.
Pistons for explosion engines. Spring. 28147.
Coke ovens. Geb. Hinselmann. 29069.
Tube scrapers. Restucci. 29133.
Coal conveyers. Barene. 29505.

1914.

Starting and ignition systems of internal combustion engines. Varley. 119.
Nut locks. Chesney. 177.
Means for suppressing explosions in mines by the use of non combustible dust. Cremer. 1493.

ELECTRICAL, 1913.

Field magnets. Rolfe. 1222.
Telephone exchange systems. Corwin. 8831.
Arc lamps. Bryen, Golding, & Pearce. 8968.
Brush holders of dynamos. White & Bacon. 9094.
Cut-outs. Downes & Venning. 9100.
Enclosed electric switches. Hope & Thomas. 9212
Variable speed dynamos. Hunt & Sandycroft, Ltd. 9260.
Alternating current dynamos. Hunt & Sandycroft, Ltd. 9261.
Electrically operated drill of the percussion type. Wall. 9893.
Generators for high frequency currents. Girardeau. 12809.
Electrical driving of reciprocating machinery. British Thomson Houston Company, and Brown. 14049.
Circuit arrangements for automatic and semi automatic telephone systems. Siemens & Halske Akt.-Ges. 14487.
Electric transformers. British Thomson Houston Company. 18663.
Electric candle lamp. Garde. 24130.
Duplex and like telegraphy. Eastern Telegraph Company, and Ryan. 25591.
Radio telegraph stations. Mellersh-Jackson. 27175.
Circuit arrangements for telephone systems. Siemens & Halske Akt. Ges. 29049.
Method of protecting the electrodes in electric arc furnaces. Bronn & Schemmann. 29259.

1914.

Circuit arrangements for telephone systems. Siemens & Halske Akt. Ges. 1792.
Suspension and tension arrangements for electric trolley wires. Siemens Schuckertwerke Ges. 4523.
Electric regulating switches. Miller & Boothman. 5505.

METAL QUOTATIONS.

TUESDAY, MAY 5TH.

Aluminium ingot	86/– per cwt.
,, wire, according to sizes, &c. ......from	107/4 ,,
,, sheets ,, ,, ... ,,	112/– ,,
Antimony......£27/10/–	to £29/–/– per ton.
Brass, rolled	$7\frac{1}{8}$d. per lb.
,, tubes (brazed)	$9\frac{5}{8}$d. ,,
,, ,, (solid drawn)	$7\frac{7}{8}$d. ,,
,, ,, wire	$7\frac{1}{8}$d. ,,
Copper, Standard	£63/10/– per ton.
Iron, Cleveland	$51/4\frac{1}{2}$,,
,, Scotch	$57/4\frac{1}{2}$,,
Lead, English	£18/17/6 ,,
,, Foreign (soft)	£18/7/6 ,,
Mica (in original cases), small	6d. to 3/– per lb.
,, ,, ,, medium	3/6 to 6/– ,,
,, ,, ,, large	7/6 to 11/– ,,
Quicksilver	£7/–/– per bottle.
Silver	$27\frac{3}{16}$d. per oz.
Spelter	£21/7/6 per ton.
Tin, block	£150/10/– per ton.
Tin plates, I.C.	$12/7\frac{1}{2}$ per box.
Zinc sheets (Silesian)	£24/15/– per ton.
,, (Stettin; Vieille Montagne)	£25/2/6 ,,

The Mechanical Engineer

An Illustrated Weekly Journal — Vol. 33, No. 851

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Telegrams: "Scientific," Manchester.
Telephone No. 6655 City.

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Advertisements, displayed, for insertion in current issue should reach our Manchester office not later than first post Tuesday morning, and small prepaid advertisements not later than first post Wednesday morning.

Smoke Abatement.

It may be remembered that last March a Smoke Abatement Bill, introduced by Lord Newton, was withdrawn on the understanding that the Government would shortly appoint a special departmental committee to enquire into the whole question of smoke abatement. This promise has now been fulfilled, and a committee appointed by the President of the Local Government Board, "to enquire into the state of the law regarding the pollution of the air by smoke, and to consider what steps should be taken to amend it." Particulars of the constitution of the committee will be found on another page. It is always easy to criticise the constitution of committees, and difficult, perhaps, to please everyone without making them unduly large; but we cannot help feeling some surprise that, as the whole question is intimately related to boiler construction and working, the committee does not include any engineer closely associated with this field of engineering. The causes of smoke, whether from boiler or domestic chimneys, and the means of preventing it, are well known to all engineers who have studied the question, and have been described in these columns on many occasions. The outside public, unfortunately, are not engineers, and the daily newspapers who often mould its opinions have published a good deal of sentimental nonsense in discussing the question, with the result that erroneous views have been created. A few years ago the outcry was entirely against the chimneys of manufacturers, who were supposed to be the sole authors of the smoky atmosphere of towns, and who were roundly abused, not only for polluting the air, but of being recklessly extravagant by pouring out of their chimneys immeasurable quantities of unburnt carbon. It is unnecessary to discuss this fallacy, but apart from it careful investigation has proved that the effluent from domestic chimneys is more deleterious to town atmospheres, as a rule, than that

from factory chimneys, and that no solution of the question can be satisfactory that does not take domestic chimneys into account. That a smoky mill chimney is objectionable and may be a nuisance which loudly calls for abatement every one will admit. To emphasize this fact does not need an accusation of extravagance, which, moreover, falls flat if the manufacturer knows better, as he often does. It should be clearly recognised that a smoky boiler chimney does not necessarily mean wasteful and extravagant use of fuel. Indeed, the question of smoke emission from boiler furnaces is rendered a delicate one owing to the fact that an efficient furnace is one that is always bordering very closely on the smoke-producing line, and may easily be forced over it by a little carelessness, or neglect, or alterations in the working conditions, over which the user has little control; and unless a reasonable latitude is allowed prosecutions for the emission of smoke may easily degenerate into persecutions. The town of Bradford has been instanced by misguided enthusiasts as a model of the extent to which a municipal authority may, by stringent regulations, control smoke emission from factory chimneys, but we doubt if Bradford can compare in this respect with many similar manufacturing towns in Lancashire and Yorkshire, where regulations are less severe; and we do know that the millowners of Bradford have been subject to a great deal of unnecessary harass and expense. The complaint of extravagance levelled against boiler furnaces could with much greater reason be directed against house chimneys. Indeed, if coal were burnt in the domestic grate with anything like the degree of economy in boiler furnaces the saving effected would easily eclipse the fabulous estimates of smoke enthusiasts regarding manufacturing wastes. Another serious count against domestic chimneys in any consideration of the smoke nuisance is that they contribute from 40 to 60 per cent. of it, and sometimes more, for it is easy to see that with a high mill chimney the smoke may be carried to a considerable distance, and a neighbouring district suffer more than that in which the chimney is located. To make smoke-prevention regulations effective it is necessary in the first place to secure a greater degree of co-ordinate action in regard to neighbouring localities than now exists; secondly, manufacturers should be protected from undue harass by frivolous prosecutions for slight offences when it can be shown that the exigencies of manufacture make it difficult to maintain uniform conditions of furnace working. In saying this we do not hold a brief for the emission of smoke from steam boilers. As a general rule it can be, and ought to be, prevented, especially with the high degree of efficiency which mechanical stokers have now attained; but it should be remembered that even the best mechanical appliances require superintendence, and from accidental causes occasionally fail to perform their duty, and if this possibility is not recognised and allowed for injustice may be easily inflicted. Where smoke emission is fairly constant it is safer to assume that the source of the trouble is inadequate boiler power rather than extravagant working of the furnaces, and the only satisfactory remedy, in the majority of cases, is additional boiler plant or, in other words, additional expenditure. As a rule the delinquent knows this and prefers to pay occasional fines rather than go to the root of the trouble, as he should be compelled to do, when a clear case is proved against him. The problem of the domestic chimney is more difficult than the manufacturing one. There are such a multitude of offenders, and no remedy can be effective unless it is applied on a large scale. Only two satisfactory ones are capable of practical application. One is the use of a fuel from which some of the more volatile elements of bituminous coal have been abstracted and yet sufficient left to secure easy ignition and smokeless burning in the ordinary domestic fireplace. The other, the supply of town gas at the cheapest possible rate, to ensure its wider use for domestic purposes. It is useless for local authorities to rail against manufacturers, and at the same time to limit the use of gaseous fuel by charging excessive prices with a view to a misleading relief of rates when it is really only a case of "robbing Peter to pay Paul."

IRON AND STEEL INSTITUTE.

THE annual general meeting of the Iron and Steel Institute was held on the 7th inst., in the House of the Institution of Civil Engineers. After the formal business of the meeting, the chair was taken by the newly elected president, Dr. Adolphe Greiner, of Belgium, who presented the Bessemer gold medal for 1914 to Mr. Edward Riley, and then delivered his inaugural address, which dealt with "By-products in the Manufacture of Steel." Following this a number of papers were read and discussed. On the following day, the meeting was resumed in the Lecture Theatre of the Institution of Civil Engineers. The president, M. Adolphe Greiner, announced that the Carnegie gold medal had been awarded by the unanimous vote of the Council to Dr. Thomas Swinden, of Sheffield. Dr. Swinden received his metallurgical training under Dr. Arnold at Sheffield University, where he achieved high distinction, having graduated in 1909 as Master of Metallurgy, and in 1913 as Doctor of Metallurgy. In 1905 the Commissioners of the 1851 Exhibition awarded him a bursary for research, and in the next year he obtained the full scholarship, which enabled him to attend the Universities of Stockholm and Upsala, and to pursue practical studies at Swedish ironworks. In 1909, the Council awarded him a Carnegie research scholarship, and the Institute had to thank him for the results of his valuable researches on molybdenum steels. Two memoirs on this subject had been presented by him, and had been published by the Institute. It afforded him very great pleasure to present to Dr. Swinden the Carnegie gold medal, and he asked him to accept his congratulations upon the success with which his labours had been rewarded. The president then announced that the Andrew Carnegie scholarships for 1914 had been awarded to Mr. H. B. Cronshaw, of Cambridge, £100 to carry out researches on refractory materials; Mr. J. W. Donaldson, of Motherwell, £100 for the purpose of carrying out researches in the gases included in various steels; Mr. R. S. G. Knight, of London, £100 to investigate fuel applications, transmission of heat, and heat balances in furnace operations generally; Mr. F. C. A. H. Lantsberry, of Birmingham, £100 to carry out research on the heat treatment of alloy steels; Mr. C. Chappell, of Sheffield, £100 to investigate the hot working of iron and steel at the Royal Technical College, Achen, Germany; Mr. A. Sander, of Karlsruhe, £100 to investigate the Feld process for the production of sulphate of ammonia in coke-oven gases; and Mr H. M. Boylston, of America, £100 to carry out a research on the relative merits of various agents for the deoxidation of steel.

Institution of Naval Architects.—The Council have accepted an invitation to hold a summer meeting in Newcastle-on-Tyne, which has been extended to the Institution by the President and Council of the North-east Coast Institution of Engineers and Shipbuilders. Meetings for the reading of papers will be held, and arrangements will be made to visit some of the principal works in Newcastle and its vicinity.

Serious Crane Accident.—An accident of a serious character occurred on the 8th inst., in the shipbuilding yard of Messrs. John Brown & Co., Ltd. It appears that a heavy plate was being lifted in the platers' shed by means of a crane when the "sling" which held it suddenly snapped, the plate crashing down to the floor, where five men were working. The men were all struck about the legs and feet. One sustained a compound fracture of the left leg; while another received compound fractures of the foot.

HIGH-POWER DIESEL ENGINES: THEIR DEVELOPMENT FOR MARINE SERVICE.*

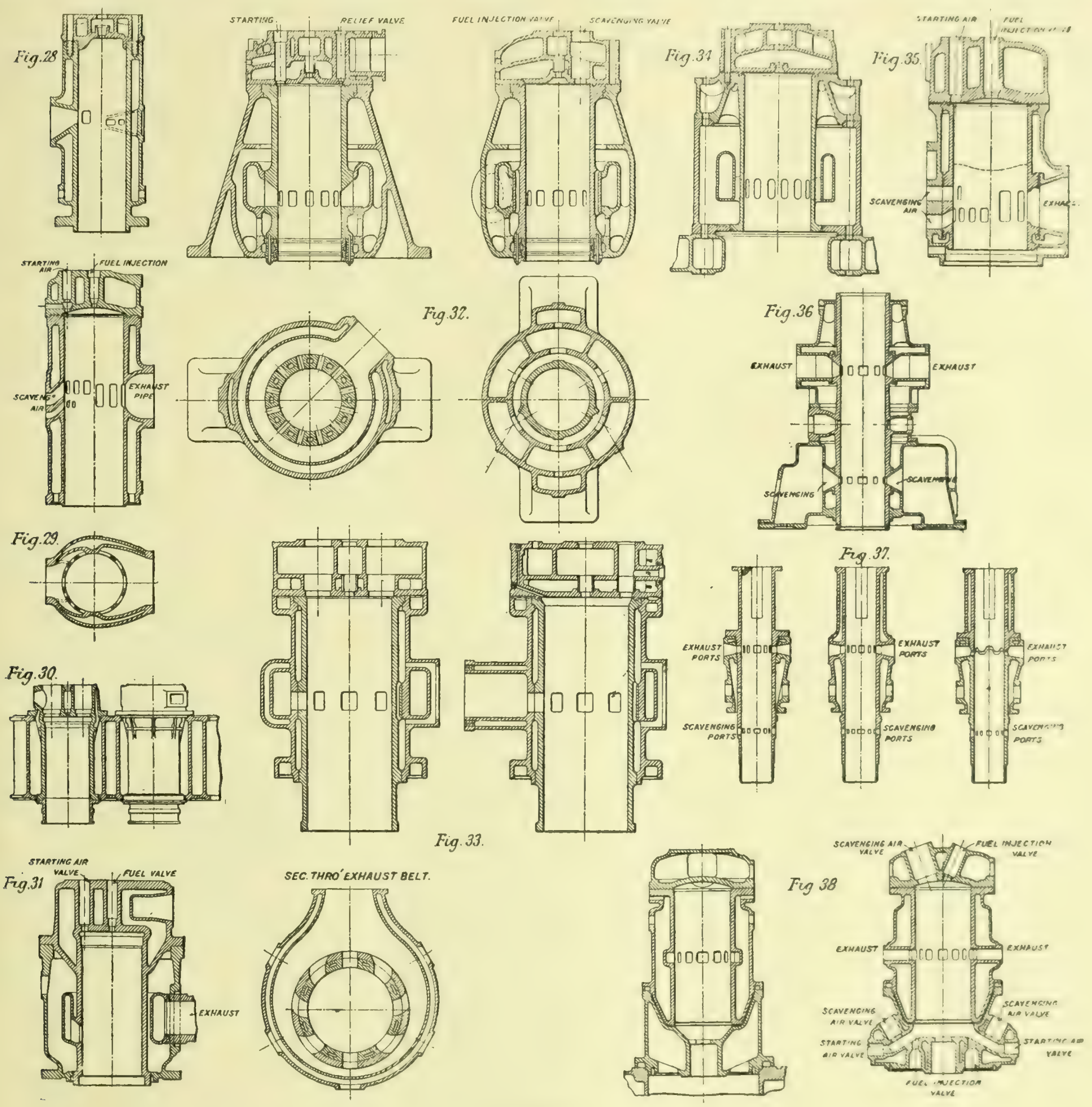
BY JAMES RICHARDSON, B.SC., A.M.INST.C.E.

(*Continued from page 431.*)

Cylinders and Cast Iron.—Those parts which are subject to both temperature and pressure stresses—namely, the cylinder, cylinder head, and piston—form probably the heart of the problem associated with the development of high-powered Diesel engines. Not only is it a question of design, but more largely one of a suitable choice of materials, depending upon foundry practice and metallurgical research. An inspection of the various methods of attack of the problem of the design of these parts suggests at once to the observer that the solution is still distant, since nearly every maker of repute adopts an entirely different means to overcome these difficulties.

Figs. 28 to 38 show that the methods for the construction of the cylinder and head may be classified in the following manner: (1) Cylinder and head in one piece. (2) Cylinder and head in two pieces (Figs. 28 and 29). (3) Cylinder and head and liner, two pieces (Figs. 30 and 31). (4) Cylinder, head, and liner, three pieces (Figs. 32 to 35). (5) Cylinder and liner in one, two, or three pieces—Junkers (Figs. 36 and 37).

Under each of these headings great variations are again to be found. Before considering the relative merits of these systems, it is well to discuss the stresses to be withstood by the parts. Firstly might be cited the casting stresses; secondly, those due to the temperature differences in the various parts, *i.e.*, that of the combustion in the cylinder, the exhaust gases in their passages, and the cooling water in its spaces; thirdly, the pressure stresses bearing throughout the cycle; and, finally, any tension stresses due to the piston load being carried through the cylinder where through bolts to the cylinder head are not provided. These, taken collectively, make a formidable group. Of these, the second stress, *i.e.*, that of temperature difference, is by far the most important, and for brevity the designs may be considered with reference to this alone.



FIGS. 28–38.

That in Class 1, which is suitable for small engines, gives immunity from trouble caused by leakage at joints, unequal

* Paper read before the Junior Institution of Engineers, April 20th, 1914.

expansions, and provides well for the passing of the heat of combustion into the cooling water. This application to cylinders of large diameter is impracticable on account of the obvious difficulties connected with dismantling, inspection, and casting, and the cost of renewal. Those in Group 2 (Figs. 28 and 29) have considerable advantage, but, as with those in Group 4 and the normal design of head, the cooling of the combustion space is not well provided for. With large cylinders the difference of expansion between the inner and outer walls in Group 2 might cause trouble. To overcome this one difficulty of cooling the combustion space, some designers have adopted the type of construction shown in Group 3 (Figs. 30 and 31), which has few other merits. The

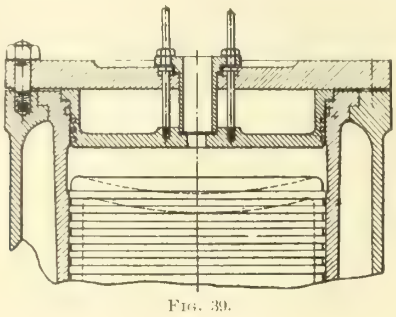


FIG. 39.

construction shown in Group 4 (Figs. 32 to 35), with a suitable design of head, will probably be that of the future, and to this further reference will be made presently. Regarding Group 5 (Figs. 36 and 37), many advantages are claimed. Construction of this type relieves the cylinder structure of all tension stresses, as, of course, may be the case with all the other groups by adopting through bolts. Fig. 38 shows two views of a double-acting cylinder, and indicates the further difficulties of design to be anticipated with engines of this type when valve scavenging is adopted.

In order to realise the advantages of the construction in Group 4, the question of the type of head must be examined, and that shown in Fig. 39 is proposed by the author. In this design a steel plate takes the piston load, and either a dished-out forged-steel or a cast-iron element accommodates the valves—preferably of minimum number, such as is possible with port scavenging—and serves to enclose the cooling water. By this means the head is greatly simplified, the head-cooling space is easily accessible for cleaning or for the insertion of coils or other cooling apparatus, and the form serves to give a lower engine and the maximum efficiency in the cooling of the combustion space. With this type of head, it is also seen that the objection which may be raised to the clump of metal where the liner is pressed into the cylinder is not valid. Suitable provision is made to accommodate the valves and to preclude the possibility of leakage of the cylinder contents into the cooling water space. An advantage of this group (4) is that to each part can be assigned the material most suitable for the functions to be performed, and the liner can be of the very best liner iron—harder than would be possible with an integral casting of cylinder and liner in one piece.

The Hopkinson method of internal water-cooling* is worthy of consideration, effecting, as it does, simplicity of cylinder, cylinder head, and piston castings. So far this method has been applied only to horizontal gas engines, and, briefly stated, consists of cooling the walls of the combustion space in lieu of external water jackets and their complications—by the impingement of jets of water, this water being

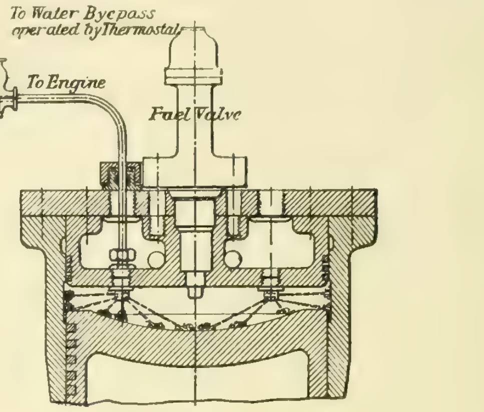


FIG. 40.

evaporated on the surfaces to be cooled, and so preventing the heat from passing through those walls. The supply of water is arranged so that all of it is evaporated into steam on reaching the surfaces. The steam so generated will form a source of power usually given to the cooling water in raising its temperature, and on this account the efficiency should be increased. On the other hand, the water may take some heat from the flame, retarding combustion and lowering the efficiency. Actual test results show that the efficiency remains the same as with water jackets, or, in other words, the expected gain in efficiency due to the water evaporation in cooling the surfaces is counterbalanced by the drop in maximum pressure. In horizontal engines where the exhaust valves are at the bottom of the cylinder no difficulty arises from deposited salts, because they readily find an outlet through this valve. The amount of water consumed is about 2·4lbs. per brake horse-power hour.

In considering the application of the Hopkinson method of cooling to vertical two-stroke high-power marine engines, the following difficulties may be expected to arise, and may be explained with reference to Fig. 40: (1) Distilled water would be used, and the production of a sufficient quantity is costly, requiring also cumbersome apparatus. Use would be made, no doubt, of an exhaust boiler. (2) With the Diesel



FIG. 41.—ETCHED. MAG. 165.

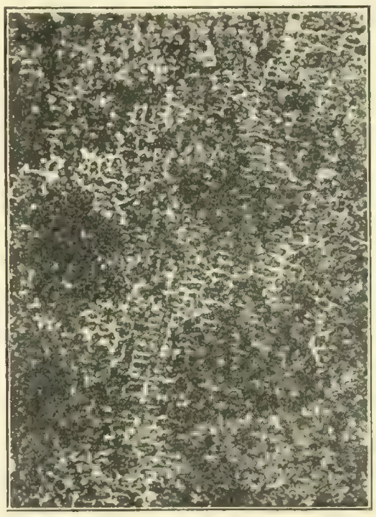


FIG. 42.—ETCHED. MAG. 33.



FIG. 43. UNETCHED. MAG. 33.

* Proc. Inst. Mechanical Engineers, July, 1913.

engine, the high compression necessitates a small clearance or compression volume, so that the form of the combustion space does not lend itself to jet cooling. Several jets would probably be necessary. (3) As the heat of combustion is relied upon entirely to ignite the fuel, it might not be advisable to inject the water into the compression space until the fuel had been ignited, although the higher temperatures all over at which the engine would run might negative this condition. (4) In any case, the head of the engine must be water-cooled, owing to the difficulty of causing the water jet to play on that surface, and because of the difficulty of cooling the fuel-injection valve without a water jacket. (5) In any case, the exhaust port bars would require to be water-cooled.

The arrangement to be tried would probably take the form as shown in Fig. 40, with two or more water sprayers for better distribution. The piston rings and the rubbing surfaces would be kept as far as possible from the cylinder head to increase the cooling effect. Further, the cylinder might be ribbed to facilitate radiation, and the piston crown centrally supported to minimise thickness and increase conduction to the crank case.

Cylinder Head and Liner Materials.—The question of the most suitable material for the head, cylinder, or cylinder liner and piston is a point regarding which no information has so far been published. Cast iron is now almost universally adopted for all these parts; cast steel has proved unsuccessful for cylinder heads, pistons, and liners, due to its coefficients of expansion and modulus of elasticity differing from those of cast iron. The conditions to be satisfied are, primarily: (1) Resistance to growth. (2) High tensile strength. (3) Hardness. (4) Shock-resisting properties. (5) Machining qualities.

By growth is meant the deterioration of the structure of the metal, due to the rapid and large fluctuations of temperature to which it is exposed. The greater the tensile strength, the thinner the wall required, and so the greater the transmission of heat from the combustion space to the cooling water. The greater the hardness compatible with machining the less the wear, and the smaller the allowance required therefor: combined with these, the iron will have a high transverse figure and good shock resisting properties.

Research regarding growth of iron of the qualities demanded by this work is, so far, inconclusive, but it can be stated, as a result of experiments carried out by authorities and by the author, that the iron should be a grey iron, of which the combined and graphitic carbons together exceed 3 per cent., roughly in the proportion of 0·5 combined to 2·5 graphitic carbon. In particular, this graphitic carbon should be of a close, small, and even structure, which makes, as explained later, for a reduction of growth.

Growth proper is increased by an open graphitic structure, permitting of the ingress of the high-temperat ire gases into the inner meshwork of the iron, and attacking probably the silicon, forming some combination of oxides of silicon. The ground-work should be pearlite, as shown in Fig. 41, and the phosphides should not in any way segregate, but should be evenly distributed, as shown in Fig. 42. As already stated, the silicon is to some extent contributory to the growth, whilst a certain percentage is necessary to ensure good machinery. This should be balanced by a suitable proportion of manganese, the ratio of manganese to silicon being not less than 1 to 1·4; in some cases 1 to 0·66 is attained. The effect of the manganese would seem to be to close the grain of the metal and so prevent the gases attacking the silicon. The phosphorus should be kept as low as is compatible with a good

TABLE V.—*Capacities of Scavenging Pumps.*

Method of Scavenging.	Main Engines. Type of Engine.	B.H.P.	No. of Cylinders.	Revs./Min.	Diam. of Cylr. In.	Stroke. In.	Volume of each Cylinder in ft.³	Scavenging Pump. No. per Engine.	S. or D. Acting.	Diam. In.	Stroke. In.	Vol. each pump in ft.³	Ratio Pump Vol. / Cylr. Vol.	Ratio. Engine Stroke. / Pump Stroke.	Type of Valves.
One Valve.	Stepped Piston	300	6	—	—	—	·5026 ratio	6	S.	—	—	·6846 R.	1·36	1	Automatic Valves
	,, ...	150	6	500	6·9	8·66	·187	6	S.	10·82 – 6·9	8·6	·272	1·45	1	,, ,,
	,, ...	900	6	260	14	23	2·05	6	S.	22 – 14	23	3·0	1·46	1	,, ,,
	,, ...	850	8	450	11·81	13·39	·85	8	S.	18·51 – 11·82	13·39	1·235	1·45	1	Automatic
	,, ...	100	4	350	7·19	11·82	·268	4	S.	11·03 – 7·09	11·82	·381	1·42	1	,,
	,, ...	100	4	600	6·89	7·88	·169	4	S.	10·83 – 6·89	7·88	·247	1·47	1	,,
Two Valves.	Crosshead Slow Running	225	4	200	11·8	16·9	1·06	2	D.	17·7	11·8	3·37	1·59	1·43	Piston Valve
	,, ,,	500	4	150	16·9	24	3·12	2	D.	24·4	17·7	4·77	1·53	1·355	,,
	,, ,,	750	4	150	19·65	27·6	4·85	2	D.	27·6	21·2	14·54	1·5	1·3	,,
	,, ,,	1250	6	170	,,	,,	4·85	3	D.	,,	,,	14·54	1·5	1·3	,,
	,, ,,	1000	4	140	21·65	31·5	6·7	2	D.	31·5	23·2	10·4	1·55	1·42	,,
	,, ,,	500	4	150	17·5	26	3·62	2	D.	28·25	15	5·42	1·5	1·73	,,
	,, ,,	1250	6	150	20	30	5·45	2	D.	36	21	12·35	1·51	1·43	,,
	Stepped Piston	100	—	—	—	—	1·6771 ratio	—	S.	—	—	2·7568 R.	1·55	1	Automatic Valves
	Crosshead Slow Running	1250	6	140	—	—	5·12 R.	—	—		—	9·74 R.	1·26	1·375	,, ,,
	Trunk Piston..........	900	6	450	13·5	15·5	1·18	2	D.	21·5	15·5	6·52	1·84	1	
	Crosshead	500	4	170	15·75	25·6	2·88	2	D.	26·5	18·5	5·55	1·92	1·39	
Four Valves.	Crosshead	1000	4	180	20·07	25·98	4·76	1	D.	36	24	28·2	1·48	1·08	Piston Valve
	,, (Type Slow Running)	1600	6	130	20	36·2	6·55	2	D.	34·2	30	16·0	1·63	1·2	Automatic
	Carels Crosshead	750	4	120	18·125	32·25	4·82	2	D.	27·25	23·5	7·94	1·65	1·37	Piston Valves
	,, ...	1500	6	130	20	36·1	6·55	2	D.	34·25	30	16·0	1·63	1·2	Automatic
	Trunk Piston..........	900	4	234	17·7	22	3·13	1	D.	28·5	22	8·1	1·30	1	,,
One Valve and Single Port.	Trunk Piston..........	500	6	310	12¼	15⅜	1·05	1	D.	24·6	15·1	4·15	1·31	1·02	Automatic
Single Port.	Trunk Piston..........	260	4	250	11·4	16·9	·99	2	D.	16·7 – 8·47	13·0	1·22	1·22	1·3	Piston Valves
	Stepped Piston	800	6	165	17·75	21·25	3·00	6	S.	22·8 – 5·6	17·7	4·7	1·56	1	With Piston Valves
	Double Piston	650	3	180	15·35	17·7	3·76	1	D.	40·5 – 16·5	19	11·8	2·1	0·935	Automatic
	,, Tandem	800	6	120	15·75	15·75	3·55	4	D.	29·5	15·75	6·24	2·34	1·0	,,
Double Port.	Stepped Piston	250	4	300	11·8	12·2	·772	4	S.	19·68 – 11·8	12·2	1·375	1·78	1	Piston Valve
	Trunk Piston..........	380	4	250	12·2	18·11	1·22	1	D.	26·5	13·77	4·4	1·8	1·31	Automatic
	Crosshead Slow Running	200	4	150	25·99	31·5	19·4	2	D.	43·31	19·69	33·5	1·74	1·59	Piston Valve
	Trunk Piston..........	310	4	220	12·21	18·12	4·92	1	D.	24·61	13·78	7·6	1·55	1·375	Automatic
	,, ...	100	4	380	7·09	9·85	·997	1	D.	14·38	7·88	1·49	1·65	1·25	,,

running iron, and the sulphur to a fair minimum. The effect of growth, as shown by micro-photographs, is illustrated in Fig. 43, where the effect of the graphitic carbon, in permitting of the ingress of the gases and the widening out and splitting of the graphitic carbon, is well shown.

TABLE IV.—"*Growth*" *in Iron.*

Iron.	Ratio of Manganese / Silicon	Increase in Weight per cent. after 21 heatings of 4 hours at 900° C.	Increase in Weight per cent. after 43 heatings of 4 hours at 900° C.	Increase in Volume per cent. after 43 heatings of 4 hours at 900° C.
A	1·238	1·790	2·822	12·3
B	1·468	2·185	3·068	16·8
C	1·530	0·888	1·830	9·2
D	1·19	2·321	3·682	16·4
E	1·393	0·770	1·887	9·3
F	Special Iron	0·245	0·460	1·7

The composition of the irons above, A—E, is as follows: Combined carbon, 0·6 to 0·68 per cent.; graphitic carbon, 2·4 to 3 per cent.; sulphur, 0·05 to 0·07 per cent.; phosphorus, 0·8 to 1·0 per cent.

The actual volumetric and weight increase of several irons, and of an iron prescribed by the author, are shown in Table

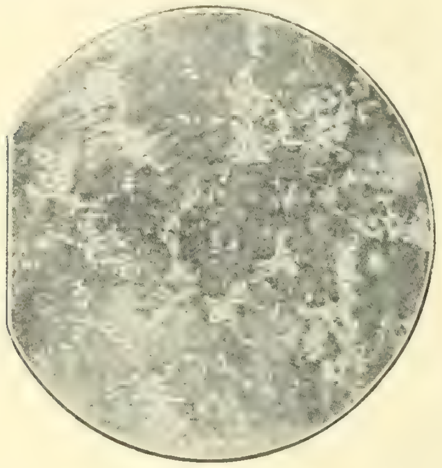


FIG. 44.—ETCHED. MAG. 33.

IV. The structure of the last-mentioned iron (F) is illustrated in Fig. 44, and is, as far as is known, unique, showing a much closer meshwork than hitherto. The tensile strength is above 20 tons per square inch, the hardness and the shock-resisting properties are ample, whilst, as will be seen, the growth has been reduced to a minimum. The running properties are exceptional, and by means of these properties many of the difficulties associated with cylinders of the largest dimensions may, it is hoped, be solved, in that not only is the iron particularly immune from growth, but, on account of its high tensile and shock-resisting properties, the thickness for any given pressure is reduced, and the transference of heat from the combustion space to the cooling water greatly facilitated. However carefully and well the mixture of the iron may be specified as regards chemical composition, great care is required in the buying of the pig in order to give the desired results, and it is absolutely necessary that a cupola be set aside to cast this one mixture only. Foundry methods generally in this country do not lend themselves to an exact regulation of the iron.

Scavenging.—One of the most open questions at the present day is the best method to be adopted for scavenging the cylinder, and in Table V. particulars are given of engines in which the scavenging is effected: (*a*) By means of one valve in the cylinder head; (*b*) two valves in the cylinder head; (*c*) four valves in the cylinder head; (*d*) one valve and the single-port method; (*e*) the single-port method; (*f*) the double-port method.

The revolutions of the engine and the type of valves adopted for the scavenging pump are stated, so that in comparing the relative sizes of pumps an idea may be formed of the efficiency of those pumps. For large engines of the future the methods likely to prove most advantageous are those of: (*b*) Two valves; (*c*) four valves; or (*f*) the double-port system.

The one-valve method does not lend itself to the most efficient scavenging and to the attainment of the highest mean effective pressures; similarly with the single-port method; whereas the four valves in the cylinder head undoubtedly make for an undesirable complication, not only in the cylinder-head casting, but with the driving gear for the valves, so that the two valves and the double-port scavenging systems would seem the most suitable.

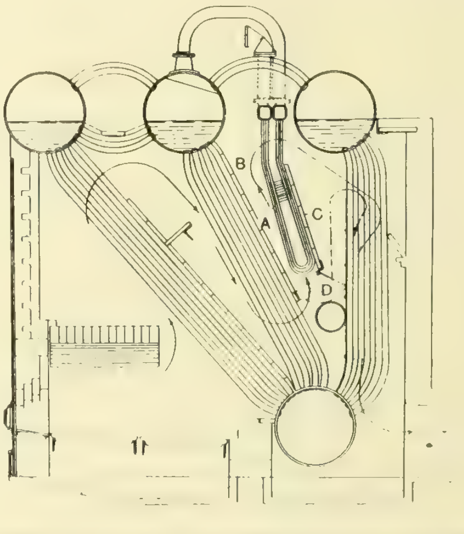
As already mentioned, the double-port system of scavenging lends itself to the augmentation of mean effective pressure, to the simplification of the cylinder head, and also of the valve gear. As to the capacity of the pumps, great latitude, naturally, is possible, since the variables are as follows: (*a*) Area of scavenging air inlet to main cylinder; (*b*) time of opening for scavenging air to main cylinder; (*c*) pressure of scavenging air desired; (*d*) size of exhaust ports and back pressure of exhaust.

It will be seen that for two valves the ratio of about 1·5 is the mean, and for double-port scavenging 1·75. The newness of this last method accounts probably for the high figure, and with greater confidence 1·6 to 1·65 will probably be found ample.

(*To be continued.*)

ARRANGEMENT OF SUPERHEATER FOR WATER-TUBE BOILERS.

WE illustrate herewith an arrangement of superheater applied to a Stirling boiler, in which the damper serving to regulate the passage of the gases is little likely to be damaged by heat, and in which the superheater tubes, when steam is not passing through them, are not subjected to much radiant heat. The U-shaped superheater A is disposed between the second bank and the rear bank of boiler tubes, being shown enclosed on three sides by baffles, one of which, B, extends along the rear side of the second bank to the upper end thereof, and the other baffle C is arranged behind the tubes of the superheater. By a deflecting damper D, hinged to baffle C, and adapted to be moved into the position shown in dotted



ARRANGEMENT OF SUPERHEATER FOR WATER-TUBE BOILERS.

lines, the superheater may be cut out completely, or when moved into the position shown in full lines the gases are compelled to pass up and around the superheater before passing to the rear bank of the tubes. The arrangement is the invention of the Stirling Boiler Company, Ltd., 58, Victoria Street, Westminster, and Mr. E. G. Constantine.

Trials of the "Vaterland."—The trials of this vessel commenced on April 28th, and lasted for several days. It is reported that the results were of a high order, and that an average speed of $25\frac{3}{4}$ knots was attained. It was estimated that with the propellers making 180 revs. per minute the vessel would travel at a speed of at least $22\frac{1}{2}$ knots, so that the estimate has been considerably surpassed.

SAFETY IN GRINDING WHEEL WORK.

A BULLETIN recently issued by the committee on safety and sanitation of the National Founders' Association, directs attention to the dangers of grinding wheel operation and how they may be overcome. The bulletin states that the speed of the ordinary grinding or emery wheel is as great as that of a fast express train and travelling at a rate of approximately one mile a minute the wheel is subject to frequent alternations of no duty and severe duty. During one moment it may be running idle, and in the next it may sustain violent shocks in rapid succession as it attacks the irregular fins of a casting or ploughs through a solid mass of metal. The grinding wheels which perform this severe service are composed of a multitude of gritty particles, artificially bonded together. Manufacturers have attained remarkable results in strongly uniting these particles; the elements of the bonding process, however, cannot be controlled with such accuracy as to ensure absolute safety of every wheel, and, in spite of most careful inspection and test, grinding wheels sometimes burst. Yet it must be conceded that the majority of such accidents are due to abuse of wheels in service and not to faulty manufacture.

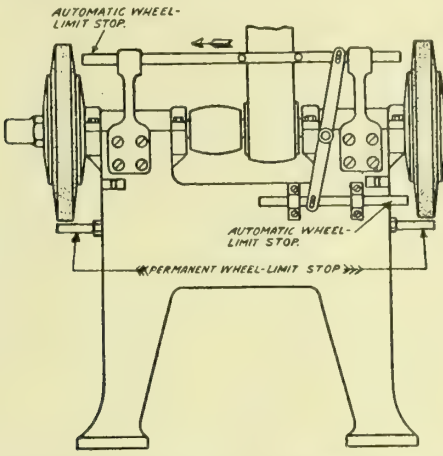


FIG. 1.—BELT-DRIVEN GRINDER WITH AUTOMATIC WHEEL LIMIT STOP.

Varied work conditions require the use of wheels of many shapes and degrees of hardness and fineness of grain. Plain wheels are obviously of stronger construction than cup wheels or other special shapes; hard wheels are of stronger composition than soft ones. Hence plain and hard wheels may be safely run at higher speeds than cup or special shaped wheels and soft grades. It has, therefore, become the custom of grinding-wheel manufacturers to attach a label to each wheel, indicating the safe maximum speed of that particular shape and grade of wheel; these recommended speeds should never be exceeded. To secure greatest efficiency of grinding wheels, it is desirable to operate them at the safe maximum speeds; most machines, therefore, are equipped with cone pulleys offering two or more speeds to equalise the wheel's cutting efficiency. The dangerous drawback of this arrangement lies in the fact that the belts on such machines may be shifted by men who do not realise the danger of overspeeding, and yet overspeeding is a frequent cause of the bursting of grinding wheels. Moreover, when a small wheel is replaced by a larger one, the operative is apt to neglect to return the belt to its proper position, thereby producing an excessive, unsafe speed.

Safety devices can be installed, with comparatively small expense, to successfully overcome these hazards. On a machine equipped with a two-step cone pulley, a belt-locking device automatically controlled by the diameter of the wheel in use, as shown in Fig. 1, will take care of the problem of excessive speed as well as that of using oversized wheels. When the cone pulley has three or more steps, the belt may be secured in proper position by the belt lock shown in Fig. 2, while the use of an oversize wheel is avoided by attaching an adjustable wheel-limit stop, also shown in Fig. 1. A sign attached to the machine stating the revolutions per minute by the use of each step is of much value.

Some managers use single speed machines equipped with permanent wheel-limit stops, as shown in Fig. 1, and are content to thus sacrifice efficiency in order to gain safety. In other plants, however, where a number of machines are used for one grade of work, single speed grinders, each of different speed, are used and wheel limit stops are provided, maximum efficiency is maintained by transferring wheels successively from low to higher speed machines as the wheels wear small. When single speed machines are equipped with protection hoods of the right diameter, these limit the size of wheel used, and other wheel limit stops are unnecessary.

When a grinding wheel is too heavy for its spindle, the latter will run out of true and may break; this may prove as disastrous as breakage of a wheel. The accompanying table gives spindle diameters which reputable grinding wheel manufacturers recommend for various sizes of wheels. Before mounting a grinding wheel upon its spindle it is well to examine the wheels for cracks; a cracked wheel when lightly tapped with a hammer will not ring clear. The wheel should slide on the spindle easily, but not too loosely, as the wheel would then run out of balance; if forced on tightly the wheel is apt to be broken. A clearance of 0·005 inch is considered satisfactory. Excessive heating of bearings and shaft should be avoided by frequent careful adjustment and by use of automatic grease cups or self-oiling bearings, amply protected from dust and grit.

It is advisable to confine within flanges as much of the wheel as is practicable, and it has been generally agreed that wheels covered by flanges less than one half the diameter of the wheels are unsafe; where feasible, the wheels should not be allowed to project more than 2in. beyond the flanges, in which case several sizes of flanges are used to suit the reduced size of the wheels. The clamping action of flanges should be effective at their circumference in order to compress the wheel at the outer edge of the flanges and not at the centre, for which purpose the flanges should be recessed toward the centre. Flanges which are not recessed clamp the wheel only where the nut compresses near the centre. Steel flanges are more dependable than cast-iron flanges.

Both inner and outer flanges should be of the same diameter, in order to prevent straining of the wheel. When flanges of one diameter are used exclusively, the inner flange should be pressed securely on the spindle; when flanges of various diameters are used on the same spindle interchangeably, all inner flanges should be keyed. This is necessary to provide a true bearing for the side of the wheel and to prevent a tendency of the nut to creep. To obtain uniform pressure of flanges upon the rough sides of the wheel, washers made of soft blotting board or of $\frac{1}{16}$in. sheet rubber should always be used between the flanges and wheels; they should be slightly larger than the diameter of the flanges. Blotting board washers are suitable for light service, rubber washers, while a little more expensive, make better cushion contact between flanges and wheels and hold the wheel more securely.

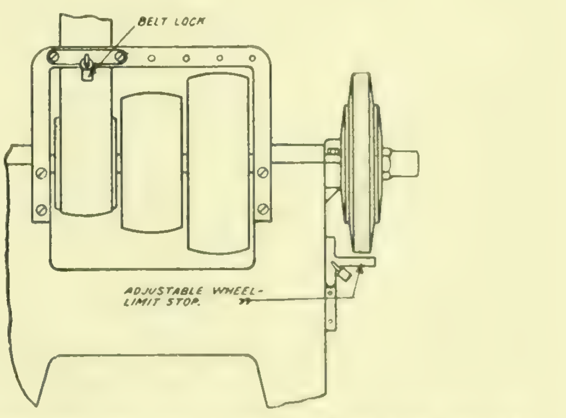


FIG. 2.—GRINDER WITH ADJUSTABLE WHEEL LIMIT STOP AND BELT LOCK.

When finally the wheel is secured upon the spindle by the clamping nut, care should be taken to tighten the latter only enough to hold the wheel firmly; otherwise the clamping strain is apt to crack the wheel. If either the wheel or the frame of the machine should vibrate abnormally after the wheel has been thus carefully mounted upon a spindle of proper diameter, and operated at normal speed, the cause may be found in weak foundations, an unbalanced wheel, imperfect bearings or shafts, or the machine itself may be too light for

the weight of the wheel it carries. Abnormal vibration is apt to shatter the wheels and this hazard must be promptly removed.

Wheels are usually in good balance when they are shipped from the factory. They, however, are subject to greater wear at some points than at others; dressing tools also dig more deeply into soft spots than into harder parts of the wheel. They should be dressed and trued at frequent intervals. The dressing tool itself should be of the guarded type. Grinding wheels should be kept in a dry place. Wheels used for wet grinding should not be allowed to stand idle in water, as the heavy water-soaked or damp portion of the wheel throws it out of balance.

Even though operating conditions may be good, grinding wheels nevertheless sometimes do break in service, because they are of brittle composition and subject to much abuse. Protection hoods, therefore, should be provided to hold within safe bounds the broken parts of a grinding wheel in case it should break; sometimes the use of safety wheels will mitigate the danger. Safety grinding wheels usually are tapered on both sides; they are clamped between tapered steel flanges, concaved to fit snugly the tapered sides of the wheels. To insure accuracy of fit, which is very important, safety flanges and safety wheels should be furnished by the same manufacturer. While safety wheels have prevented many injuries, they are not absolutely dependable. The unbalanced momentum of a broken wheel is often sufficient to spread the flanges and allow broken parts of the wheel to escape. Moreover, even safety flanges cannot retain broken pieces which may fly from the unconfined rim of a grinding wheel. Safety wheels are chiefly desirable in special cases when the character of the work absolutely prohibits the use of hoods, and even

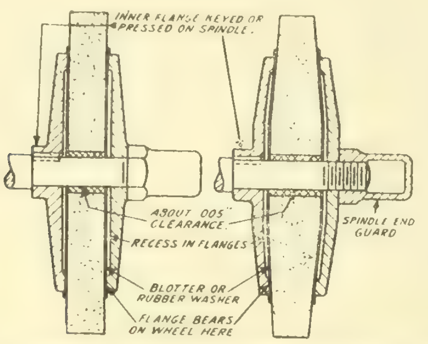


Fig. 3.—Proper Mounting of Straight and Safety Wheels.

then extraordinary care must be taken to maintain favourable operating conditions and moderate speeds.

A protection hood is the best and safest method to guard against injuries from broken grinding wheels. When possible the hood should be of such construction as to serve also as a dust hood which, when connected with a suitable exhaust system, will eliminate the injurious effects of grinding wheel dust and at the same time protect against accidents. Such combination hoods are regularly made and form a part of modern machines; it has also been found practicable to install such hoods upon old machines. Cast steel or rolled steel hoods are safer than cast-iron hoods; the latter are not dependable, except for light wheels which are rarely used in foundries. Hoods should be amply strong to serve their purpose. The inside diameter and width of the hoods should be sufficiently larger than the corresponding diameter of the wheel to allow proper clearance. The hood should also enclose the spindle end, but if the character of the machine will not allow this, a separate guard can be provided to prevent workmen's clothing from catching in the spindle threads. The hood should enclose the wheel as much as possible and leave an opening only large enough to satisfactorily apply the work to be ground. If the opening is too large it will permit the escape of broken parts of the wheel and thus frustrate one important purpose for which the hood is designed; it will also require greater volume of air for proper exhaust.

Grinding dust should be carried away by an adequate exhaust system. Where this cannot be done, the eyes of operatives should be protected from the sharp and injurious grinding and metal dust by approved eye protectors. Sometimes an adjustable glass shield is used, arranged to slide in a metal frame attached to the machine. For the safe and convenient handling of work while it is being ground, grinding wheels are usually provided with work rests; these must be adjustable and workmen should be encouraged to keep them as close as possible to the wheel, for otherwise the workman's fingers may be drawn between the wheel and work rest, or pieces of the casting, or even the casting itself, may become wedged in the opening and do damage to the wheel, or to the workman, or to both. The clamps for fastening the work rest in place must be effective in their action, so that work rests may not be forced away from the wheel at a critical moment.

Table of Smallest Spindles for Various Sizes of Grinding Wheels.

Diameter of Wheel.	Maximum Thickness of Grinding Wheels, in inches.													
	1	1¼	1½	1¾	2	2¼	2½	3	3½	4	4½	5	5½	6
8	¾	¾	¾	¾	¾	¾	1	1	1	1	1¼	1¼	1¼	1¼
9	¾	¾	¾	¾	1	1	1	1	1	1¼	1¼	1¼	1¼	1¼
10	¾	¾	¾	1	1	1	1	1	1¼	1¼	1¼	1½	1½	1½
12	¾	1	1	1	1	1¼	1¼	1¼	1½	1½	1½	1½	1¾	1¾
14	1	1	1	1¼	1¼	1¼	1¼	1½	1½	1¾	1¾	1¾	1¾	1¾
16	1	1¼	1¼	1¼	1½	1½	1½	1¾	1¾	1¾	1¾	1¾	1¾	2
18	1¼	1¼	1¼	1½	1½	1½	1¾	1¾	1¾	1¾	2	2	2	2
20	1¼	1¼	1½	1½	1¾	1¾	1¾	1¾	1¾	2	2	2	2	2¼
22	1¼	1½	1½	1¾	1¾	1¾	1¾	2	2	2	2	2¼	2¼	2¼
24	1½	1½	1¾	1¾	1¾	1¾	2	2	2	2	2¼	2¼	2¼	2½
26		1¾	1¾	1¾	1¾	2	2	2	2¼	2¼	2¼	2¼	2½	3
28			1¾	1¾	2	2	2	2	2¼	2¼	2¼	2½	3	3
30			1¾	2	2	2	2	2¼	2¼	2¼	2½	3	3	-
32			2	2	2	2	2¼	2¼	2½	2½	3	3	-	-
34			2	2	2	2¼	2¼	2½	2½	3	3	—	-	—
36			2	2	2¼	2¼	2¼	2½	3	3	-	-		- -

In order to avoid striking of hard blows on sides of wheels when handling heavy or cumbersome castings, a chain hoist will prove an economical investment; by its use castings may be safely held while workmen guide the castings against the wheel; or suitable tables or rests can be devised for the same purpose. Wherever belts are used on grinding wheels they should be enclosed in suitable guards constructed of sheet iron, expanded metal or heavy wire screen, attached to angle iron frames; sometimes wooden guards are used, because more economical, and, when properly made are of protective value. The belts should be guarded to a height about 7ft. above the floor. To prevent stumbling against the machine, the floor about the machine should be kept free from castings or other obstructions.

The foregoing recommendations are adaptable to machines now in use. If, however, new machines are to be installed, it is advisable to insist that they be equipped with every safeguard. Grinding machines are mostly of the belt-driven type. Electrically driven machines are now finding increased use; they are usually equipped with constant-speed motors, which, together with protection hoods and devices to limit the size of grinding wheels, give safe conditions of operation. Some manufacturers equip their machines with variable-speed motors in order to maintain maximum operating efficiency; such machines should have devices to guard against overspeeding, for instance, through automatic connection between the motor speed regulator and the diameter of the grinding wheel. In the case of portable or swing-frame grinding machines, it is equally important that all practicable protecting devices should be provided; in all cases protection hoods can be applied and provisions can be made against overspeeding.

Labour Departmental Committee Appointed.—The Treasury has appointed a Committee to consider whether any, and, if so, what steps might be taken with a view to regularising the total demand for labour from year to year, and in different seasons, by adjusting the distribution of public work conducted or given out by Government departments and local authorities with reference to the state of employment in the particular trades from time to time.

FAILURES OF HEAVY BOILER SHELL PLATES.*

BY SIDNEY A. HOUGHTON, A.M.INST.C.E. (SHIP AND ENGINEER SURVEYOR, MARINE DEPARTMENT, BOARD OF TRADE).

IN spite of the fact that the knowledge of the manufacture and science of steel making increases year by year, it is unfortunately true that failures of plates which have passed the usual tests are not yet eliminated. That this should be the case with the lower grade descriptions of mild steel would not give cause for criticism, but that they should occur with the heavy boiler shell plates used in marine boilers, which are made from the highest class of mild steel, and generally from special charges, is a matter which is worthy of special investigation. The only paper on the subject seems, however, to be the able one by Mr. J. T. Milton, chief engineer of Lloyd's Register, on "Fractures on Large Steel Boiler Plates," which is given in the "Proceedings of the Institution of Naval Architects, 1905." This paper is of considerable importance, but practically deals fully with only one case, which was investigated by Prof. Arnold, though four or five others are described. The importance of failures of



FIG. 1. MAGNIFIED 50 DIAMETERS.

this nature has long been recognised, and careful investigations have been made by the Board of Trade and the Classification Societies into fractures discovered in the boiler shops, but as financial questions often arise between the steel-maker and the boiler-maker it is not as a rule possible to publish the results at the time, and indeed in some instances the actual causes have not been definitely ascertained.

The cases described in the present paper are selected from those which have come under the author's notice during the last 15 years. Some of the plates were not under Board of Trade inspection, but through the courtesy of Lloyd's Register of Shipping and the British Corporation for the Survey and Register of Shipping facilities were afforded for testing and examining the plates in conjunction with their surveyors. It should be stated here that the plates had all been tested in the usual way, at least one tensile and two bend tests being taken from opposite corners, and in some instances from each corner, and that the results were satisfactory; also that the plates were bent cold in the rolls to the necessary radius, and that all rivet holes were drilled in place.

The principal details of the failures described are stated in the accompanying tables, and a short description of the circumstances attending them is given before considering the causes of failure as a whole. It must be understood that the opinions as to the causes of failure are those of the author and are not necessarily those of the Board of Trade or of the Registration Societies concerned. In some instances the conclusions arrived at cannot be fully verified, but the author

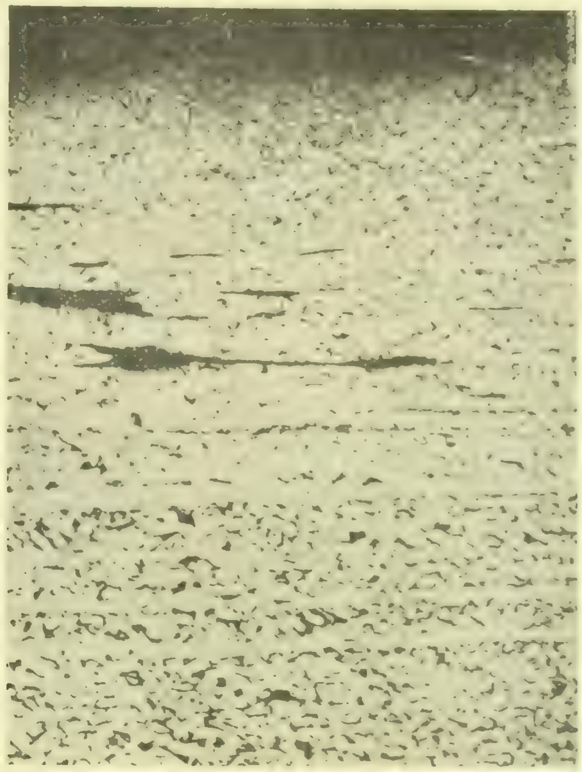


FIG. 2. MAGNIFIED 50 DIAMETERS.

hopes that by thus publishing them it will be possible to obtain criticisms and suggestions which will lead to the discovery of the correct ones.

All the plates were made by the acid open-hearth process with the exception of one, which was made by the basic open-hearth, and all the sections of which photographs are shown were cut longitudinally, that is, in the direction of the greatest length of the plate, unless otherwise stated. These sections were therefore at right angles to the cracks, which were all transverse ones. Practically all the sections were etched with a solution of picric acid in amyllic alcohol to which a few drops of nitric acid were added. Picric acid by itself is hardly sufficiently powerful to distinctly mark out the ferrite crystals in mild steel, but with the addition of a little nitric acid these are shown clearly without discoloration, whilst the picric acid blackens the pearlite suitably for photographic purposes. In all cases complete sections of the plates were examined, and in dealing with material of this nature this is absolutely necessary. This is mentioned because some metallographic workers appear to use sections only about ⅜in. square or even less: the author has experienced no difficulty in preparing sections ¾in. or ⅞in.

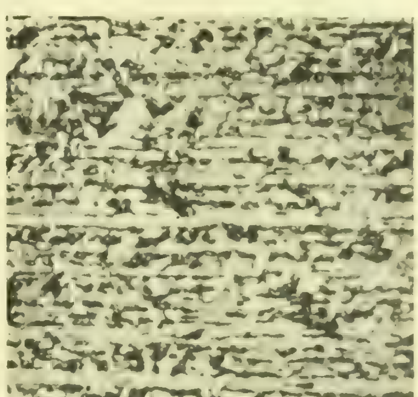


FIG. 3. MAGNIFIED 50 DIAMETERS.

* Paper read before the Iron and Steel Institute, May, 1914.

square, and with these dimensions the thickest shell plate can be examined in two parts only. If the sections are protected by a cover-glass secured by Canada balsam in the usual way, and then mounted on a glass slip with white lead, they will keep indefinitely and will be available for examination at any time.

A few of the analyses given cannot wholly be relied on, at any rate so far as those elements liable to segregation are concerned, as the drillings were not taken right through the plate. It is always advisable in dealing with heavy plates to take at least two analyses, one from the two outer quarters of the plate and one from the inside half, thus indicating if segregation exists.

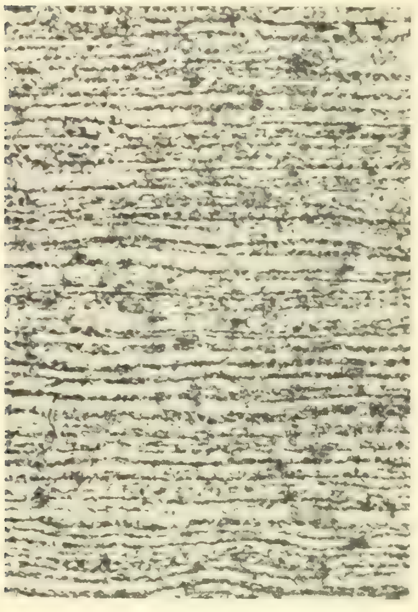


FIG. 4. MAGNIFIED 50 DIAMETERS.

The cases considered are not dealt with in chronological order, but are divided into three classes, as follows: (A) Plates in which partial cracks only have occurred. (B) Plates which have cracked right across in the boiler shop. (C) Plates which have failed under the hydraulic test.

Class A.—In most of the plates of this class the cracks have occurred in dressed portions, and hammering has been one of the chief causes of failure, though many plates are abnormal in some other characteristic. It is hoped that this list of failures may help to prevent the use of this obnoxious practice in future.

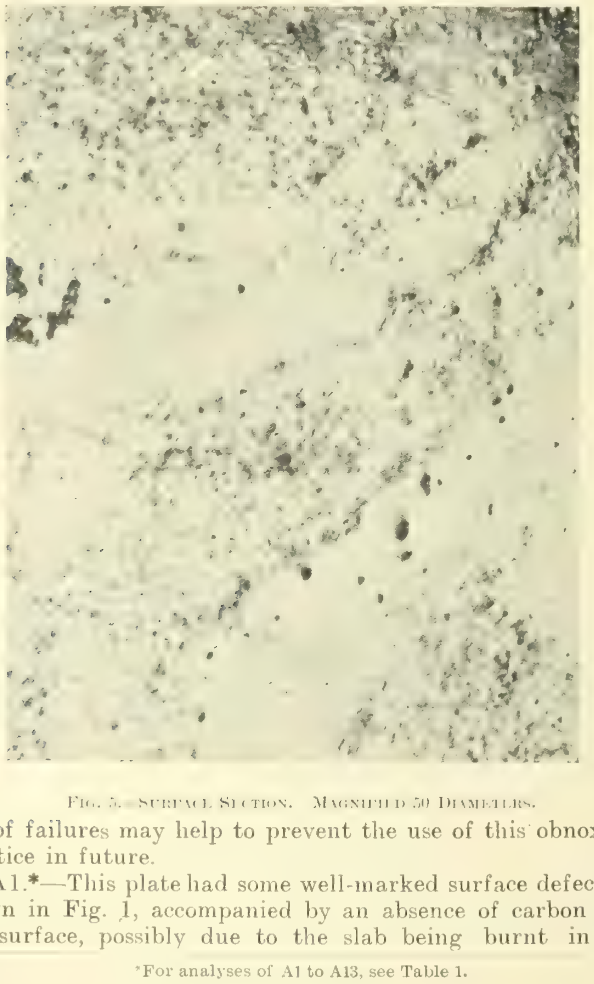


FIG. 5. SURFACE SECTION. MAGNIFIED 50 DIAMETERS.

A1.*—This plate had some well-marked surface defects, as shown in Fig. 1, accompanied by an absence of carbon near the surface, possibly due to the slab being burnt in the soaking pit; it will be noticed that this part is sharply defined from the normal structure. As can be seen in the photograph the surface has been well hammered, and it is not surprising that the steel in this part gave way when bent. The structure near the centre was very coarse, and is in great contrast to that on the outside, which may be due to the slab not being uniformly heated. There is considerable difference between the original tests and those in the vicinity of the fracture, and as the analysis does not agree with the latter, it is probable that the drillings were taken from another place and that the plate was far from uniform in composition, though it should be mentioned that there is no sign of segregation in the sections examined.

*For analyses of A1 to A13, see Table 1.

A2.—Both the sulphur and phosphorus were very high in this plate, and the latter formed some carbonless bands near the surface, thereby helping to cause roughness and conferring extra brittleness on the part which was hammered. This metal contained a great number of blowholes which increased towards the centre, and it may be remarked that in several instances an excessive number of blowholes appear to indicate an inferior quality of metal, though at first sight there seems no reason why any material difference should be noticeable if the metal is stressed in the same direction as that in which it is rolled. The general structure is very lamellar in character, which it is suggested may be produced if the slabs are soaked too long, especially when the phosphorus content is high. The failure of this plate was due to hammer-dressing of surface defects produced by the minor segregations of phosphorus

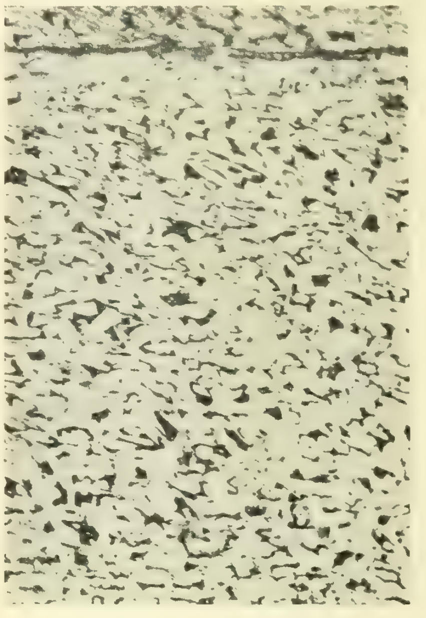


FIG. 6. MAGNIFIED 50 DIAMETERS.

A3.—The primary cause of the failure of this plate was probably the large carbonless area shown in Fig. 2, due possibly to the surface of the slab being burnt or decarbonised in parts; there are also some carbonless bands below caused by phosphorus segregations. The structure towards the centre of this plate is of a lamellar character, with a moderate number of blowholes and some compound crystals, which would indicate that the finishing temperature was high. The author calls "compound crystals" those which are composed of several separate ones of ferrite and pearlite, and which, in fact, constitute the entire structure of mild steel heated to a temperature of 1,000° C. There were no signs of hammer-dressing on this plate.

A4.—The structure of this plate was extremely lamellar, as shown in Fig. 3, and there were an excessive number of blowholes which could be better seen before etching. The phosphorus was quite high enough and there was a considerable amount of arsenic; the plate was also hammer-dressed, but there were no signs of segregation near the fracture.

A5.—This plate shows a structure considerably different from the preceding cases; it was said to have been annealed, but if so the annealing was very inefficient. The general structure was very fine and mostly lamellar, as shown in Fig. 4; it is, in fact, too small to be produced by annealing, and the plate must have been finished at a very low temperature, thereby setting up internal stresses. Near the surface are some good examples of phosphoretic minor segregations. The crystals in these parts are of huge size compared with those of the steel itself. Fig. 5 is a horizontal one at the surface, showing the evil effect of these segregations, and it is evident that they afford a good starting point for a fracture.

TABLE I.

Class and Number.	Thickness of Plate.	Weight of Plate.	Weight of Ingot.	Percentage Weight of Plate of Weight of Ingot.	If Annealed.	Tensile Tests.	Tons per Sq. Inch.	Elongation in 8in. per cent.	Carbon.	Manganese.	Sulphur.	Phosphorus.	Silicon.	Arsenic.	Structure.	Photograph. Fig. No.	Nature of Failure.	Probable Causes of Failure, with Estimated Percentage Values.
	In.	Tons. Cwt.	Tons. Cwt.															
A1	1⅝	4 5	7 10	56·6	No.	Original At fracture	29·9 26·3	23 24	0·23	0·46	0·04	0·053	0·03	—	Carbonless bands and flaws at surface. No segregation. Slightly increased carbon towards surface.	1	Crack 8in. long and ¾in. deep, in centre of plate when being bent.	Hammer-dressing (35) on surface flaws (60); finished too hot (5).
A2	1⅜	—	—	—	No.	At fracture, long. At fracture, trans.	28·4 28·5	30 18	0·19	0·5	0·067	0·065	0·037	—	Very lamellar. Large number of blowholes, which increase towards centre.	—	Crack 2¼in. long.	Hammer-dressing (30); metal porous (15); phosphorus too high (20); surface defects (55).
A3	1 11/32	3 10	8 10	41·0	No.	At fracture, long. At fracture, trans.	30·0 29·4	28 27	0·17	0·324	0·046	0·057	0·027	—	Carbonless bands at surface; lamellar in centre. Moderate number of compound crystals.	2	Crack 9in. long near edge.	Surface defects (70); finished too hot (5).
A4	1 3/16	5 2	—	—	No.	Original At fracture, long. At fracture, trans.	29·8 28·4 28·5	24 27 25	0·19	0·674	0·054	0·06	0·025	0·053	Very lamellar; large number of blowholes.	3	Crack 3in. long.	Hammer-dressing (50); lamellar structure (10); excessive phosphorus and arsenic (25).
A5	1 17/32	6 2	11 0	55·4	Yes (?)	Original At fracture, long. At corner of plate, trans.	30·3 28·6 29·0	28 26 14	0·21	0·572	0·066	0·059	0·19	—	Fine lamellar, with broad, carbonless bands at surface; segregation at centre.	4, 5	Crack 21in. long.	Surface segregation (35); plate rolled cold, producing internal stresses (40); central segregation (15); lamellar structure (10).
A6	1⅝	4 16	7 15	62·0	No.	Original At fracture, long. At fracture, trans.	21·7 30·9 29·9	27 30 28	0·22	0·545	0·028	0·054	0·047	—	Very coarse; large number of compound crystals, increasing towards centre.	—	Boiler completed; crack 17¾in. long from rivet hole.	Hammer-dressing (35) on surface defects (40); plate rolled at too high temperature (15).
A7	1 11/32	3 16	8 10	44·7	No.	Original At fracture, long. At fracture, trans.	30·6 27·6 28·0	23 32 28	0·19	0·49	0·038	0·057	0·015	—	Fairly normal.	—	Crack 13in. long from rivet hole.	Hammer-dressing (60) on surface defects (40).
A8	1 11/32	2 2	8 10	24·7	No.	Original* At fracture, long.† At fracture, trans.	30·0 28·7 28·6	23 23 27	0·155 0·2	0·463 0·49	0·03 0·04	0·054 0·0[illegible]	0·027 0·013	—	Large; lamellar towards centre; carbonless bands at surface.	6	Crack 8in. long near one side.	Hammer-dressing (30) on surface defects (40); plate rolled too hot (10); lamellar structure (5).
A9	1 11/32	3 16	8 10	44·7	No.	Original	30·3	22	0·21	0·5	0·035	0·056	0·014	—	Large; lamellar towards centre; many compound crystals.	7	Crack 4in. long near one side.	Severe hammer-dressing (50) on surface defects (45); plate rolled too hot (5).
A10	[illegible]	4 7	8 10	51·1	No.	Original	30·1	23	0·2	0·54	0·04	0·058	0·011	—	Fine near surface, lamellar towards centre; blowholes near surface.	8	Two cracks, 3in. long, one at end, and one [illegible] at side [illegible] dressed part.	Hammer-dressing (40) on surface defects (40).
A11	[illegible]	3 17	7 14	50·0	No.	Original At fracture, long. At fracture, trans.	30·8 31·3 28·9	25 26 6	0·35	0·6	0·042	0·67	0·021	—	Very coarse; composed largely of compound crystals; segregation at centre.	10, 11	Boiler completed; two cracks found in dressed surfaces.	Excessive rolling temperature (40), excessive phosphorus (25), hammer-dressing (20), segregation (15).
A12	[illegible]	4 10	8 0	56·3	No.	Original At fracture, long. At fracture, trans.	30·8 30·4 30·4 to 29·9	28 24 13 9	0·18	0·52	0·048	0·055	—	—	Large amount of sulphide of manganese flaws. Segregation of carbon phosphorus and sulphur.	12	Two cracks in dressed part, one 3½in. and one 1½in. long.	Hammer-dressing (35) on surface defects (35); segregation (30).
A13	[illegible]	3 11	6 10	54·6	No.	Original	29·0	24	0·2	0·6	0·046	0·049	0·029	—	Very coarse; compound crystals towards centre.	13	Cracked [illegible]	Hammer-dressing (25) on surface defects (40); [illegible]

* Surface. † Middle.

The outlines of the phosphoretic iron crystals can be seen also in this photograph.

A6.—The defect in this plate was only found under the hydraulic test when a leak was observed near a rivet hole; and on further examination it was seen that there was a crack starting from the rivet hole in a dressed part. This crack did not go right through the plate, and was only shown by the water passing round the rivet itself. The length of the crack was 17½in. and the depth 1⅛in., and it was of the "bubble" description. The tensile tests were satisfactory, but the structure shows that the plate was finished at a high temperature, probably not less than 800° C., and that the plate had been hammered in the dressed part to conceal a surface defect.

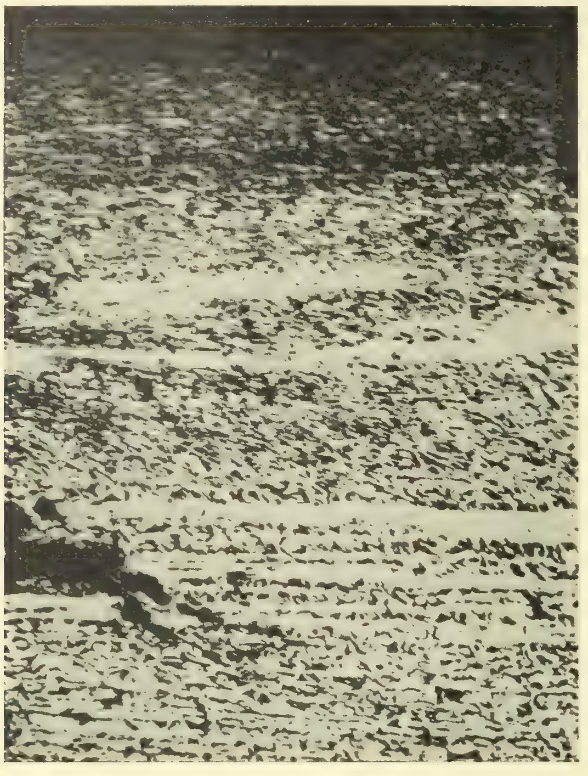


FIG. 7.—MAGNIFIED 50 DIAMETERS.



FIG. 8.—MAGNIFIED 50 DIAMETERS.

A7.—This plate was partly riveted into the boiler, when it was found that there was a transverse crack 13in. long, extending from one of the rivet holes, this being in a part of the plate which had been dressed. The tensile tests taken near the crack gave satisfactory results, with the exception of one which failed with an extension of only 4 per cent. due to a concealed surface defect. The bend tests were similarly good, except one taken alongside the crack which failed from a surface defect. The analysis gave nothing unusual, though the phosphorus was somewhat high; whilst the microscope showed that the structure was fairly normal, but that the surface had been severely hammered to conceal surface defects arising from the outside of the slab being overheated.

A8.—This plate had been curved to radius when an irregularly-shaped crack, about 8in. long, was noticed in a dressed part. On the piece containing the fracture being broken, the crack was seen to be very uneven in character, extending to about half the thickness of the plate. The tensile and bend tests were satisfactory, except bends made from the dressed portion, which failed at a small angle. Analysis showed that whilst the carbon decreased towards the surface the phosphorus increased, and this latter condition showed itself, as usual, as carbonless bands. There were also some blowholes at the surface which had been severely hammered (see Fig. 6). The internal structure differed considerably from that at the outside, being of a marked lamellar character, and was decidedly coarse for the thickness of the plate.

A9.—This plate had also been curved to radius before a crack 4in. long was found in a dressed part near one side. No tensile tests were taken, but bend tests were made from the dressed portion. These all failed at a comparatively small angle, and it is evident that this test is a simple and efficient one for disclosing surface defects which have been hammered. The analysis is fairly normal, but the microscope showed some large flaws and carbonless bands near the surface. The latter had been hammered apparently with a flogging hammer, judging by the distortion produced, as shown in Fig. 7; and it was a foregone conclusion that a plate so treated would fail when bent.



FIG. 9.—PIECE OF SHELL PLATE BROKEN THROUGH "BUBBLE"-SHAPED CRACK.

A10.—Two cracks in dressed portions of this plate were observed after it had been bent to radius, one being near the end and the other about midway along one of the sides, the latter crack being exceptional in that it was of a rectangular character, one part being transverse and the other longitudinal. Bend tests from the dressed portion failed, and a section near the rectangular crack revealed the nature of one of the defects which it had been attempted to hammer down. This was evidently caused by some foreign substance which had been rolled in, and produced the depression shown in

Fig. 8. It will be noticed that the structure is deformed by hot work, and also that the top surface has been hammered. There were in addition some carbonless bands and flaws near the surface, and, though it sounds paradoxical, there was an

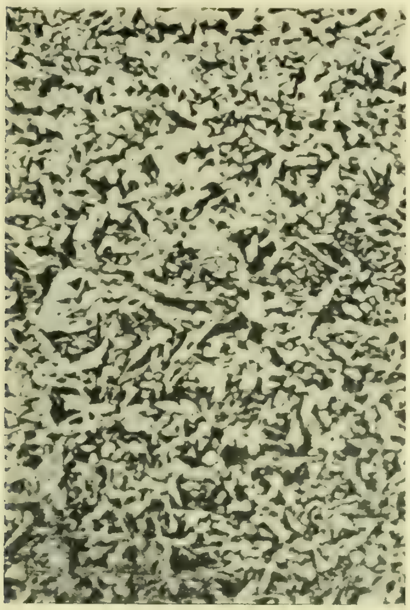


FIG. 10.—MAGNIFIED 50 DIAMETERS.

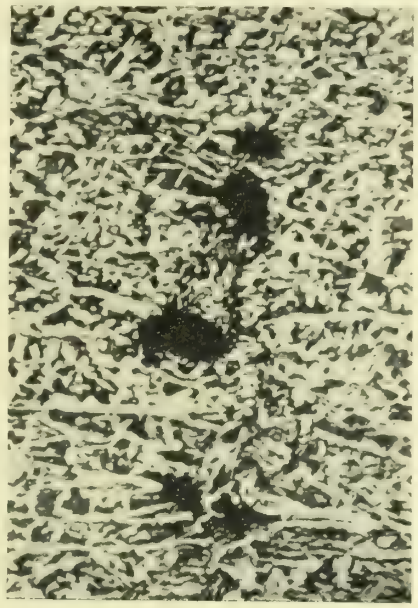


FIG. 11.—MAGNIFIED 50 DIAMETERS.

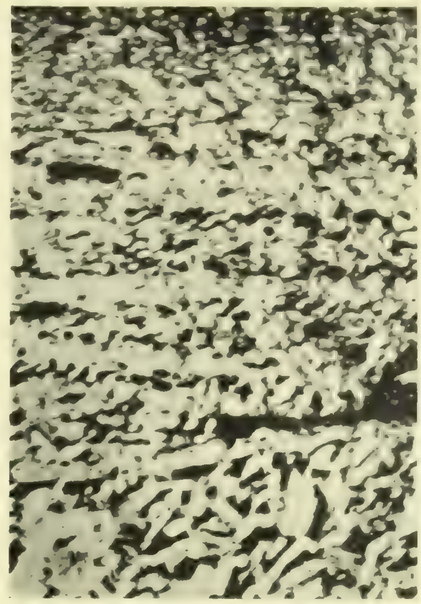


FIG. 13.—MAGNIFIED 50 DIAMETERS.

increase of carbon towards the surface, there being no signs of segregation.

A11.—The cracks in this plate were not discovered till the boiler was ready for the hydraulic test, when two were seen, one 8¼in. and one 9in. long, in dressed parts not far from the middle of the plate. After the plate had been removed a portion was cut off and broken through the 8¼in. crack, which was then seen to be of the "bubble" description (*see* Fig. 9). The tensile tests gave varying results, and showed

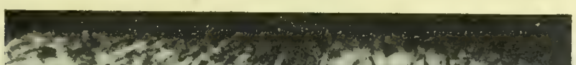


FIG. 12.—MAGNIFIED 50 DIAMETERS.

that the plate was segregated, but all the bend tests were satisfactory. The analysis showed excessive carbon and phosphorus, and indicated that the material was unsuitable for a shell plate. In preparing the sections for the microscope it was noticed that the metal was soft and powdery to the file, similar to that of a steel casting, and, on examining the structure, this was found to approximate to that of an imperfectly annealed casting (*see* Fig. 10), showing that the plate had been rolled at a grossly excessive temperature. Fig. 11 is taken from the centre of a tensile test piece near the point of fracture, and shows the form of segregation, and also the manner in which the metal gives way at this part, owing to its want of ductility. At the fracture this is shown by the familiar white line caused by the crystalline break of this part of the metal. This plate was also hammer dressed, possibly in order to hide defects due to the surface being burnt. The following abnormal features occurred in this plate: excessive rolling and finishing temperature, excessive carbon and phosphorus, hammer dressing and central segregation, so that its failure was not a matter for surprise.

A12.—When this plate was being bent in the rolls a tinkling noise was heard, and on examination two cracks were found in a dressed portion, one 3¼in. and the other 1½in. long. This part of the plate was cut out and broken, when it was seen that the principal crack was of the "bubble" description (*see* Fig. 9), so that it would seem that this form of crack can be produced by bending the plate. The transverse tests taken in the vicinity of the cracks all gave poor results, and some failed with a square fracture and a white line indicating segregation. The structure of the plate shows a large number of minute sulphide of manganese flaws, which increased towards the centre both in size and quantity; it seems that the fissures shown on the fractured surfaces (Fig. 9) are due to this and not to piping. The general structure is rather lamellar, with carbonless bands near the surface, which had been hammered in the dressed portion. This is clearly shown in Fig. 12, which illustrates a good example of a phosphoretic band, the boundaries of which are clearly marked, and also of the effect of hammering the plate. Heavy central segregation occurred in this plate, where the carbon would amount to about 0·5 per cent. From the microscopical examination it is probable that the amounts of carbon and sulphur given in the analysis are underestimated.

A13.—In this instance a crack about 8in. long was found in a dressed portion of the plate near the centre. The analysis obtained was normal and the mechanical tests were satisfactory. The structure showed heavy blowhole and surface flaws, with carbonless bands near the surface (*see* Fig. 13), which had been hammered. The general structure was very coarse, indicating high temperature of rolling and slow cooling, and possibly this plate had been piled.

(*To be continued.*)

THE INSTITUTE OF METALS: MAY LECTURE.

THE annual May lecture of the Institute of Metals was delivered by Prof. E. Heyn, of Berlin, on Tuesday last, at the Institution of Mechanical Engineers, Engineer Vice-Admiral Sir Henry J. Oram, K.C.B., F.R.S., President of the Institute of Metals, being in the chair. Prof. Heyn said that it was a well-known fact that the welfare and convenience of modern mankind was, to a very considerable extent, influenced by the achievements of the engineer. People admired his work, and were daily confiding life and health to his creations. But only few were conscious of the fact that engineering work was, to a great extent, dependent on the possibility of manufacturing sound materials fit for the purpose and of keeping them sound in the course of the manifold processes that these materials required to go through until they were assembled into the admirable engineering structures presenting themselves to the public eye. Few persons were conscious of the enormous amount of thought bestowed on the question of soundness of materials by thousands of men fighting continuous struggles against the numerous hidden dangers involved in the intricacy of structural material and working strenuously towards its perfection and reliability. Certain structural members might fail even without being subjected to stresses in service. For instance, it had often been observed that condenser tubes made out of brass cracked simply when stored up in the yard. Some articles made out of this metal, when exposed to atmospheric influences, underwent an alteration to such an extent that they might be crumbled between the fingers. Similar phenomena could be stated in structural members made out of other metals and alloys, when they were manufactured under unfavourable conditions, which lead to serious internal strains. The author said that he had made a special study of the phenomena connected with internal strains, investigating their causes and devising a method for measuring their amount. In his lecture the author dealt specially with the internal strains produced by cold working of metals (cold drawing, cold rolling, cold hammering, &c.). He showed that by these operations under unfavourable conditions internal strains might be set up in structural members which came close to their resisting power, so that even trifling additional strains caused by external forces or other circumstances (scratching of the surface, unequal heating or cooling, slight corrosion by certain agents which were contained in the atmosphere or by certain paints) might lead to unforeseen fracture. He discussed the means for removing or diminishing such dangerous internal strains, and illustrated his lecture by numerous samples taken from the domain of practical engineering.

HOME OFFICE REGULATIONS RELATING TO WORK IN SHIPBUILDING YARDS.

THE following regulations, dated April 4th, 1914, have been made by the Secretary of State under Section 79 of the Factory and Workshop Act, 1901, to apply to the construction and repair of ships in shipbuilding yards.

These regulations shall not apply to the construction or repair of a ship not exceeding 150ft. in length measured from the fore part of the stem to the after part of the stern post on the range of the upper deck beams, except in awning or shelter-deck vessels, in which cases the length is to be measured on the range of the deck beams next below the awning or shelter deck. These regulations shall come into force on May 1st, 1914. It shall be the duty of the occupier to comply with Part I. of these regulations. It shall be the duty of all persons employed to comply with Part II. of these regulations.

PART I.—DUTIES OF OCCUPIERS.

1. A sufficient supply of sound and substantial material shall be available in a convenient place or places for the construction of all stages.

2. All uprights, thwarts, and other supports used for the erection of stages, and as far as reasonably practicable the stages themselves, shall be erected by competent persons specially but not necessarily exclusively employed for that purpose by the occupier: Provided that this part of the regulation shall not apply to such adjustment or shifting of the staging from time to time by any workman as may be necessary to meet the varying requirements of his work. All stages shall be securely constructed of sound and substantial material, and shall be of sufficient width, as is reasonable in all the circumstances of the case, to secure the safety of the persons working thereon.

3. When any plank or planks forming a stage extend less than 1ft. beyond the inside edge of the support upon which they rest they shall be securely fastened to prevent slipping.

4. The main gangway giving access to the upper parts of the ship shall be securely protected by upper and lower handrails on each side; and there shall be safe means of access to all places in which any person is required to be employed.

5. All ladders used shall be of sound material and of sufficient length to give safe access to the part they are intended to reach. They shall be maintained in good condition and be adequately secured to prevent slipping

6. All ventilator holes, manholes, and dangerous parts of other openings in deck shall be provided with temporary covers in good repair, or other sufficient protection, which shall be maintained in position except when necessarily removed in the course of work.

7. All parts of a ship on which work is being carried on and the approaches to such parts, shall be efficiently lighted in such manner as is reasonable in all the circumstances of the case to secure the safety of the persons employed. If portable lamps, including hand lamps carried by the workmen, are used for any part of such lighting, they shall be maintained in good condition. Oil lamps shall be provided with properly fitting screw lids or stoppers.

8. When a stage has to be dismantled and in all cases where materials or articles have to be lowered from a height, adequate precautions shall be taken to secure the safety of persons employed or passing below.

9. Suitable means of removing injured persons from the place of accident shall be provided, and suitable arrangements shall be made for first aid treatment.

10. A competent person or persons shall be appointed to exercise supervision with regard to the requirements of these regulations, and to enforce the observance of them.

PART II.—DUTIES OF PERSONS EMPLOYED.

11. Every person employed who becomes aware of any defect in the plant or gear which he is using or may be required to use shall forthwith report the same to the occupier or his manager or foreman or any person appointed in pursuance of Regulation 10.

12. No person employed shall leave any loose articles or materials lying about in any place from which they may fall on persons working or passing.

13. No person employed shall throw down tools, planks, or loose material from the stages, decks, or other parts of the vessel, without observing the precautions required in pursuance of Regulation 8.

SMOKE ABATEMENT: DEPARTMENTAL COMMITTEE APPOINTED.

THE President of the Local Government Board has appointed a Departmental Committee "to consider the present state of the law with regard to the pollution of the air by smoke and other noxious vapours and its administration, and to advise what steps are desirable and practicable with a view to diminishing the evils still arising from such pollution." The Committee will consist of the Right Hon. Russell Rea, M.P. (chairman); Mr. H. Brevitt, Prof. J. B. Cohen, Colonel H. Hughes, Mr. J. F. MacCabe, the Right Hon. Lord Newton, Captain H. R. Sankey, Mr. B. Duncomb Sells, Mr. P. C. Simmons, Mr. E. D. Simon, Mr. W. B. Smith, Mr. H. O. Stutchbury, Mr. Christopher Turner, and Sir Aston Webb, with Mr. E. A. Faunch, of the Local Government Board, as secretary.

THE FLYING-MACHINE FROM AN ENGINEERING STANDPOINT.*

BY FREDERICK WILLIAM LANCHESTER, M.INST.C.E.

1. *The Air Considered as the Permanent Way.*—In approaching the subject of the flying machine from the engineering standpoint, it is desirable to devote attention in the first instance to the air considered as the "permanent way." When the atmosphere is quiescent a gliding model or a flying-machine carves its way through the air in rectilinear flight as if supported on a perfectly-laid track—a far more perfectly-laid track than the railway engineer has hitherto shown himself able to lay down. Under such conditions the

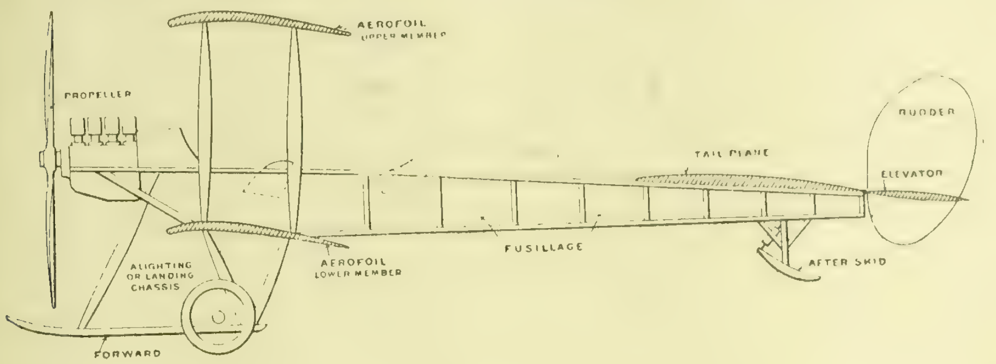


FIG. 1a.

aeronautical constructor requires to know the weight and coefficient of traction of the machine, the velocity of flight, and the maximum gradient it is required to climb, the problem then resolving itself into the provision of a screw-propeller of sufficient diameter and appropriate pitch to supply the necessary thrust reaction, and the fitting of a motive-power engine (and, if necessary, gearing) to drive the said propeller at its correct speed. The horse-power needed is calculated just as in any other case of propulsion or traction. In addition, the engineer needs to be able to calculate the stresses necessary to the design of his aerofoil and fusillage structure, and to design a suitable alighting chassis. For the present we shall assume that we have to deal with a machine in being, and devote our attention to the peculiarities and properties of the aerial highway to which the machine has to be adapted and to adapt itself. In Fig. 1 is represented the flight-path† of a hypothetical machine, plotted from a mathematical equation. The hypothetical machine differs from an actual flying-machine, or glider, inasmuch as it is assumed to be quite small in comparison to the minimum radius of curvature of its flight-path, its whole mass is taken as concentrated at its centre of gravity (consequently it has no moment of inertia about its transverse axis), and it is presumed to experience no resistance in flight, or alternatively, it is supposed to have a propelling force constantly applied equal at every instant to its resistance. Referring to Fig. 1, it is seen that the straight line flight-path is represented by a horizontal line, path No. 1; here the velocity of the machine is equal to that acquired by a body falling freely through a distance H_n constituting the distance between flight-path No. 1 and the datum line. For this hypothetical machine there is an infinite number of other possible flight-paths, the whole series being represented by the equation—

$$\cos\theta = \frac{H}{3\,H_n} + \frac{C}{\sqrt{H}}$$

from which the samples given are plotted.

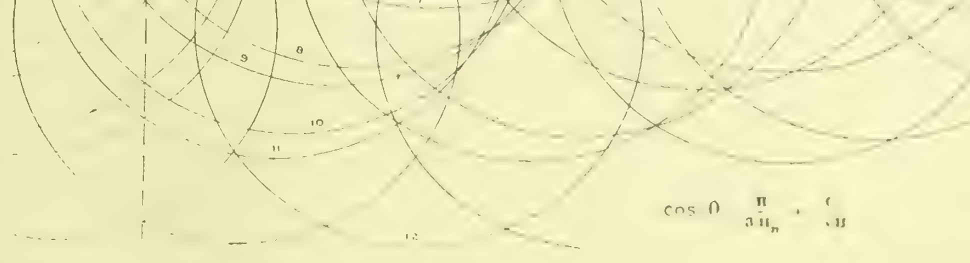


FIG. 1.

It will be seen that these comprise two notable special cases:‡ firstly, we have the straight line path No. 1, secondly, the exact semi-circle No. 7.

The flight paths, or "phugoids," Nos. 1 to 6, of less amplitude than the semi-circle, are those which are of chief concern from our present point of view, the cases beyond the semi-circle, in which the curve has no point of inflection, and in which the machine "loops the loop," are in the main only interesting from the point of view of the mathematician and the student of "trick flying." These inflected curves have been more fully plotted in Fig. 2. In both Figs. 1 and 2 the velocity at any point is that corresponding to a body falling freely from the datum line. Thus, given the normal or natural flight velocity V_n, the scale of the chart is determined by the calculation of H_n from the equation of the falling body

$$H_n = \frac{V_n^2}{2g}.$$

Although, as already stated, the flight paths given in Figs. 1 and 2 represent, strictly speaking, a hypothetical machine that only faintly resembles an actual machine, the difference has but little effect on the validity of these flight path charts. I have shown§ that in the main the effect of moment of inertia about the transverse axis is to cause the amplitude of the oscillation to increase, so that the machine, or glider, will pass by imperceptible stages from one curve to another in the order they are numbered on the chart, eventually leading to instability. I have also demonstrated that the assumption of a constant horizontal propulsive force, in place of a force always in equilibrium with the resistance, has the reverse effect, and tends to damp out an oscillation and diminish the path amplitude. We may thus in any free-flight model, or glider, have the flight-path unstable, neutral, or stable, according to which (if either) influence predominates. In an actual flying-machine we may also have the flight-path unstable, neutral, or stable, but here experience has shown that a skilled pilot is well able to handle a machine even though its natural flight path may be unstable.‖ In spite of this, calculation shows that, speaking generally, machines as flown to-day are not far, one way or the other, from the neutral state. From the engineer's point of view it is unimportant whether the flight path stability is inherent in the machine, or whether, so to speak, the finishing touches have to be given by the pilot himself.

The point I wish to make clear at the present juncture is that the curves, plotted from a mathematical equation, do actually apply with reasonable experimental exactitude to

* The "James Forrest" Lecture, 1914, delivered before the Institution of Civil Engineers, May 5th, 1914.

† Reproduced from Fig. 12 of "Aerial Flight," by F. W. Lanchester, Vol. II.

‡ There is a further special case, when the value of H [illegible] the flight path becomes [illegible] H.

§ "Aerial Flight," Vol. II., [illegible]

‖ This kind of stability is frequently termed [illegible].

models and to machines in flight. Thus a disturbance acting on any model in free flight will set up periodic undulations in the flight-path, and these have within the limits of experimental observation both the time period and phase length corresponding to their theoretical values in relation to the flight velocity. Some experimental determinations,* show-

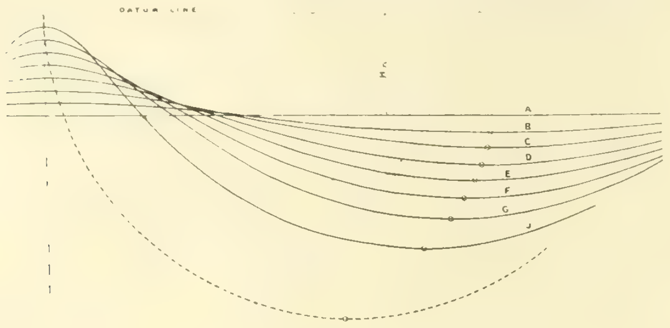


FIG. 2.

ing the reality of this relation made with models in free flight, are given in Table I.

TABLE I.

	1	2	3
Flight velocity	14·0	14·0	10·0
Theoretical phase length ....feet	27·0	27·0	15·5
Measured phase length ....feet	26·0	—	—
Theoretical time period ....second	1·93	1·93	1·55
Measured time period ....second	1·9	1·83	1·37

The phugoid, or flight-path chart is capable of useful application in more ways than one. Any movement of the

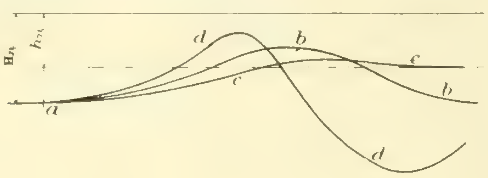


FIG. 3.

tail-plane or "elevator," for example, by altering the attitude of the main aerofoil causes the machine to become self-supporting at a lower or higher velocity, that is to say, alters its natural velocity, and we thus may represent such a change in the manner indicated in Fig. 3. Here a machine is presumed flying at a certain velocity corresponding to the height H_n, its elevator at the point a is altered to correspond to a lower flight velocity corresponding to a height h_n; this is equivalent to altering the scale of the chart at that point, and the subsequent path of the machine is represented by the phugoid curve $a\ b$. This path may undergo damping, either



FIG. 4.

due to the inherent stability of the flight-path or due to the intervention of the pilot, as shown by the line $a\ c$. In the case of a model of unstable flight-path with no intervention from the pilot the flight-path becomes one of augmented amplitude, $a\ d$.

When a machine is fitted with an elevator (or adjustable tail-plane) of large surface it is possible for the pilot to take such entire charge of his machine that he appears to be designing his own flight-path curves rather than modifying or damping the natural curves of the equation. It is quite true that this is one way to fly; it is, in fact, the old Wright method of flying, the original Wright machines having been furnished with a front elevator carrying little or no load. That type of machine, however, may be regarded as a thing of the past. The Wright machine could be "piled up" by inattention or want of skill at any moment, and if once its flight velocity fell below a certain value, either from want of attention on the part of the pilot, or from a wind gust from abaft or other cause, the pilot was definitely unable to restore his normal flight condition; it is for this reason that the Wright type of machine has been abandoned.*

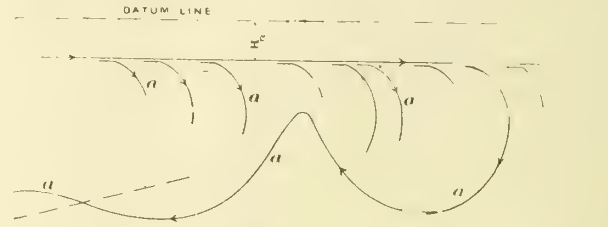


FIG. 5.

2. *Catastrophic Instability.*—Before entirely quitting this branch of the subject attention will be directed to a point first raised by me within the last 12 months under the title of "Catastrophic Instability." It is a curious fact that, although the author and other investigators had been studying the question of stability by various methods for some 20 years, more or less, and such items as longitudinal stability, lateral stability, and a form known as asymmetric or "rotative" stability, have been "catalogued" and investigated, both theoretically and experimentally, a form of instability which may in practice be far more serious and deadly has until quite recently escaped notice. There are certain types of flight model, of which the ordinary "ballasted plane" is an example, in which the flight-path is ambiguous. In the case of the ballasted plane† the position is quite simple. This

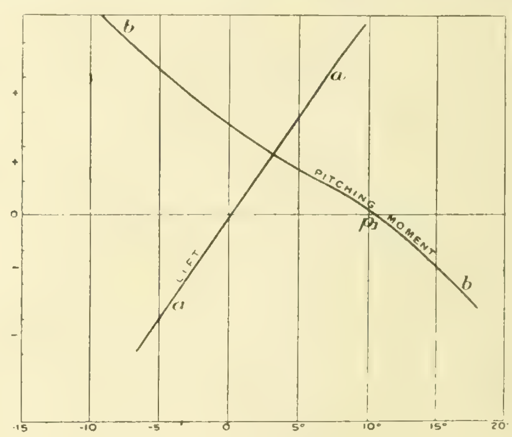


FIG. 6.

type of model is symmetrical, it has no "upside down": if launched at its correct flight-velocity to travel on flight-path No. 1 (Fig. 1) it is equally capable of travelling on an alternative flight-path intermediate to those numbered 11 and 12, the only determining factor being whether at the moment of launching the pressure reaction is in an upward or downward direction. A very slight want of skill in launching one of these ballasted planes gives at once the inverted flight-path

* Tabulated from "Aerial Flight," Vol. II., § 69.

* Practically the whole of the distinctive features of the early Wright machine have disappeared to-day; for example, the tailless machine is a thing of the past, nearly every modern machine is fitted with a tail plane. The forward elevator is obsolete or nearly so. The twin propeller has given place to the single propeller in almost every case. The gear-driven propeller also has been abandoned. The vertical four-cylinder or motor-car type of engine has proved itself inadequate. The exposed position of the pilot, engine, &c., has gone never to return. The Wright method of launching on runners and alighting on skids also is a thing of the past. The biplane construction and the fore-and-aft vertical surface have to some extent survived, but these features were in no wise new when adopted by the Wright Brothers.

The wing warping and vertical rudder (neither feature in itself new), operated by the Wright Brothers from one control lever in common, are nowadays operated from two entirely separate controls.

† A rectangular plate of mica, conveniently 0·003in. thick, 8in. by 2in., ballasted at the centre of the leading edge. Compare "Aerial Flight," Vol. I., page 231; Vol. II., page 4.

(Fig. 4); likewise a gust or disturbance acting on a model of this kind in flight, may be sufficient to invert the flight-path and determine its downfall. From our present point of view, regarding the air as the "permanent way," the position is as though the model, or machine, were continually crossing a number of facing points arranged, not quite as on a railway, but in a vertical sense (Fig. 5), so that the machine is always in danger of being switched off on to an inverted flight-path *a a*, if an aerial disturbance of the right kind and sufficient magnitude and duration happen to be encountered.*

In my opinion the soundest way to avoid danger from this cause is experiment in a wind channel with scale models, both of the aerofoil and of the machine as a whole, prepared from the working drawings.

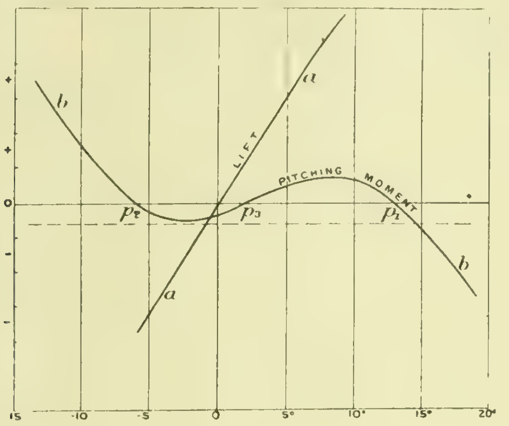


Fig. 7a.

According to the evidence that has up to the present been collected the lift diagram for any machine passes without break of continuity from positive to negative values, and the angle of inclination is a single-valued function of the pressure reaction *a a*, Figs. 6 and 7. The pitching moment in some cases is a curve of similar character, *b b*, Fig. 6, in other cases it is of the form *b b*, Figs. 7a and 7b, the latter of which represents the case of the ballasted plane. In Fig. 6 the model may be considered as catastrophically stable, but in Figs. 7a and 7b there is instability. There are three positions, or attitudes, of the machine, at which the pitching moment is zero, the two outer two, p_1 and p_2, defining respectively the stable positions of normal and upside-down flight,

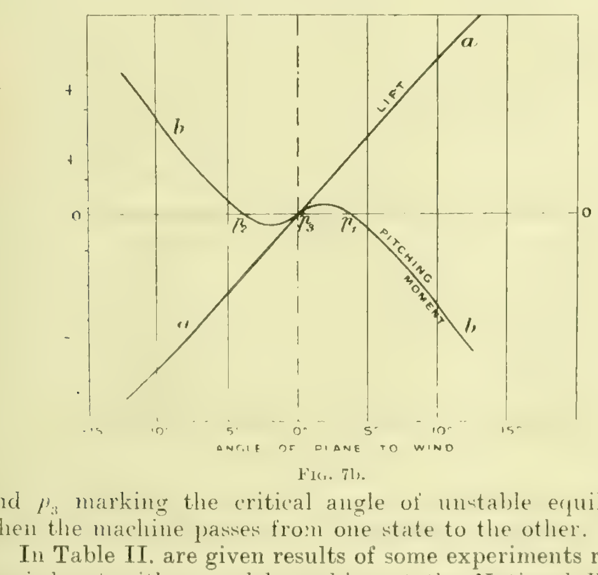


Fig. 7b.

and p_3 marking the critical angle of unstable equilibrium when the machine passes from one state to the other.

In Table II. are given results of some experiments recently carried out with a model machine at the National Physical Laboratory. These were not directed to the point in question, but incidentally serve as an apt illustration, and roughly form the basis of the plotting, Fig. 7a.

In the experimental figures as tabulated the evidence of catastrophic instability is seen in the column headed pitching

Table II.

Angle of Pitch.	Pitching Moment.	
Chord as Datum.		
14	+0·0264	
12	+0·0152	
10	+0·0063	
		< Angle of stable equilibrium upside down
– 8	–0·0015	
– 6	–0·0059	
– 4	–0·0049	
– 2	–0·0014	
		< Critical angle of catastrophic change of flight path.
0	+0·0030	
2	+0·0070	
4	+0·0102	
6	+0·0210	
8	+0·0218	
10	+0·0127	
12	+0·0072	
14	+0·0026	
		< Angle of stable equilibrium right way up.
16	–0·0043	
18	–0·0173	

moment; whenever there are three changes of sign the model is catastrophically unstable.

Referring to Fig. 7a it may be observed that the character of the pitching-moment curve depends primarily upon the

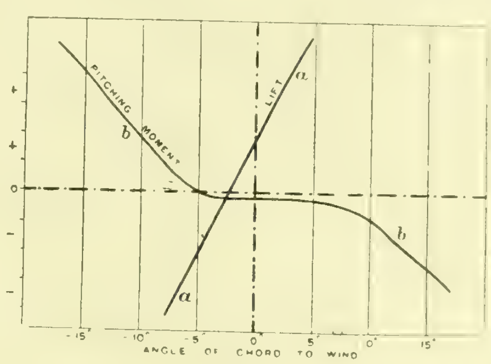


Fig. 8.

form of the aerofoil, the position of the centre of gravity, and the effective area of the tail member. By altering the angle of the tail plane (or by altering its effective angle by moving the flap known as the elevator) the datum line of Fig. 7a is in effect raised or lowered, but the form of the curve itself is not materially changed. It is evident, therefore, that a given machine may be catastrophically stable within certain limits of the adjustment of its elevator; that is to say, referring to Fig. 7a, it will be seen that the datum line may either cut the curve once or three times; the range of adjustment of the elevator that results in cutting the curve once leaves the machine catastrophically stable, but when the elevator is adjusted so that the datum line cuts the curve three times the machine is catastrophically unstable. In such a case as that shown by the dotted datum line in Fig. 7a, in which the machine is catastrophically stable, the form of the pitching-moment curve is still open to objection. Not only is it always possible for the pilot to bring about catastrophic instability by an otherwise well-intentioned movement of his elevator, but the restoring couple for pitching beyond a small amplitude ceases to follow even approximately the straight line law, a fact that inevitably imperils the flight-path stability. Even when, as illustrated in Fig. 8, the pitching-moment curve *b b* never passes the horizontal, and so catastrophic instability is no longer to be feared, the conditions

* The disastrous nature of this sudden inversion of the flight path may be gauged from the fact that it represents in effect a complete reversal of gravity, the machine is accelerated downwards with a force comparable to that previously giving it support, and any loose tools, instruments, or fitments, including the pilot himself, are liable to be jettisoned by the machine, whose subsequent career is an upside-down flight carried out on its own account. The facts on record relating to the fatal accident to Major Merrick at the Central Flying School (October 3rd, 1913) point strongly to catastrophic instability as the cause.

are not satisfactory, since there may be a considerable change of attitude of the machine without giving rise to any commensurate restoring couple.

The undesirable kink in the pitching-moment curve, shown in Figs. 7a, 7b, and 8, is due to the movements of the centre of pressure of the aerofoil itself in relation to the position of the centre of gravity. The tail plane alone will give a pitching-moment curve of the type illustrated in Fig. 6, but the fore and aft change of position of the centre of pressure of the aerofoil, at different angles of attack, gives rise to a pitching-moment curve whose exact character depends upon the position of the centre of gravity. Should this correspond to a positively loaded tail, a curve of the type *b b*, Fig. 9, will result. This, superposed on the tail component, imparts to the pitching-moment curve of the complete machine the kink shown in Fig. 7a.

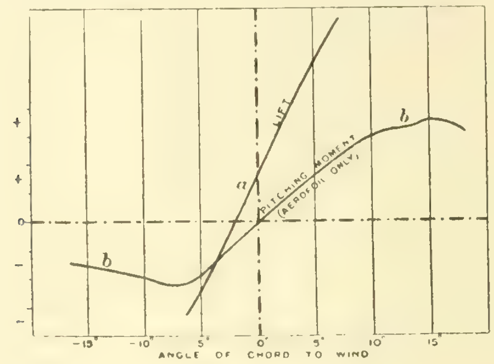


Fig. 9.

In order to definitely make sure of a satisfactory pitching-moment curve for the complete machine, the pitching-moment curve of the aerofoil alone should, at no point, exhibit an inverse trend. To achieve this it is necessary to bring the centre of gravity appreciably in front of the most forward position of the centre of pressure of the aerofoil, so that the tail-plane will under all conditions carry a slight negative load. Taking it as a basis that at the worst point the pitching-moment curve for the aerofoil alone shall be horizontal (the form of curve shown in Fig. 8), the geometrical construction given in Fig. 10 may be employed to give a suitable location to the centre of gravity; here the locus of the centre of pressure (as experimentally determined) is given by the line *a a a*, the pressure-reaction curve is shown by the line *b b b*, the dynamic zero being on the line O Y. A number of tangents to the pitching-moment curve are drawn at random from points on the axis O Y, and are produced a distance

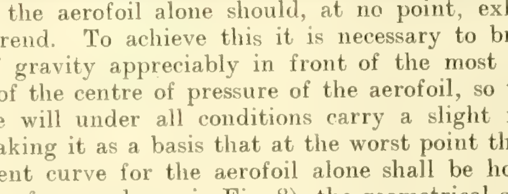


Fig. 10.

equal to their own length beyond the point of contact, the extremities of these tangents defining a curve *d d d*. Draw *g g* tangent to *d d d*, then the centre of gravity should be situated on, or forward of, the line *g g*. The location of the centre of gravity on this line gives a pitching-moment curve for the aerofoil alone whose point of inflection is horizontal (as in Fig. 8). If we assume the machine flown at a normal speed corresponding to the maximum lift/drift ratio of the aerofoil (curve *c c c*), the centre of gravity in this particular case is one-eighth of the chord length in advance of the centre of pressure. Assuming the tail length equal to three times the chord (as in the B.E. 2 type of the Royal Aircraft Factory, whose outline elevation is shown in Fig. 1a, this is equivalent to a negative load on the tail equal to 0·04 (4 per cent.) of the weight of the machine.* A machine so ballasted may be regarded as absolutely secure from catastrophic instability and as having a pitching-moment curve of an adequate character.

In connection with the present subject it is worthy of remark that in a well-designed aerofoil the most forward position of the centre of pressure is never far removed from the point of maximum lift/drift ratio.† This fact is of importance, inasmuch as it permits a considerable range of movement round about the attitude of normal flight without introducing grave irregularities in the pitching-moment curve. Were it not for this the required conditions might frequently be far more difficult of fulfilment than is actually the case.

* A similar conclusion was reached by the author some eight years ago, based on an entirely different method of investigation. For model experiment a negatively loaded tail was found to be advantageous; the figure 0·035 is given in "Aerial Flight," Vol. II., page 335. It is desirable to work with a less proportion of negative load from the point of view of keeping the resistance low; evidently the matter is one for compromise.

† This is not in the nature of a coincidence, a well-designed aerofoil at its attitude of least resistance meets and leaves the stream-lines representing the relative air-flow (in the region of its mid-section) conformably. Under these conditions small changes of attitude one way or the other do not cause any abrupt change in the aerodynamic system. Such expedients as flattening the extremities and giving a reflex curve to the trailing edge are also found to be of service.

(To be continued.)

GAS ENGINES FOR STEEL PLANTS.

In a paper on "Power Problems in Steel Mills," recently presented before the American Institute of Electrical Engineers, Mr. F. G. Gasche, of the Illinois Steel Company, referred to the shortcomings of the gas engine as an exclusive prime mover for steel-mill service, more particularly the four-cycle twin tandem type of large capacity, driving alternating-current generators. The unsuitability of this type of prime mover for exclusive use, granted that under steady load conditions the gas engine had enough advantages to warrant its supplying a part of the power required, was based, in part, upon the following facts:—

Investigation had not yet given sufficient data for determining accurately the extent of the loads thrown suddenly upon the prime movers in steel mills, particularly motor-driven mills. Supplying sufficient spare capacity in gas-engine units to carry these peak loads was accordingly a matter of guesswork, and especially so because the regulation of the gas engine of the type under discussion was hopelessly inadequate to the instantaneous character of the mill load variations. The weight that was required to be put into flywheel and rotor parts to equalise the load was entirely out of proportion to the effective capacity of the units, and the drag resulting from the inertia of these moving parts made the question of adequate regulation impossible of satisfactory solution. The variation in torque inherent in the gas engine of this type as a prime mover, even under ideal conditions of constant load, was another essential handicap to its harmonious adaptation. The use of the storage battery for the absorption of the peak loads, while conceded to be an essential auxiliary to the gas engine plant, as installed at some of the steel plants, did not provide a sufficiently flexible nor economical regulator of the load to offer a solution of the difficulties. In contrast to the gas engine, the steam turbine was offered as an alternative, the regulation of which was much more closely adaptable to the conditions of steel-mill service, both as to economy of operation under normal average load and under peak loads. He suggested that a design of prime movers for a steel mill might provide 70 per cent. of the capacity in gas engines, and 30 per cent. in steam turbines, in which proportion the probability of the power plant's adapting itself to the load conditions would be improved in every respect.

ASQUITH'S DRILLING MACHINE.

A DESIGN of drilling machine for drilling holes through any portion of a wide plate, at one setting thereof and without the necessity for employing a long overhanging arm to carry the drill spindle, is shown in the accompanying cuts, of which Fig. 1 is an end elevation, Fig. 2 a side or front elevation, and Fig. 3 a diagrammatic plan of the tool. The radial arm A is mounted upon a pillar projecting from a carriage mounted upon the cross slide B and is provided with a power or hand feed or both for moving the carriage to any required position

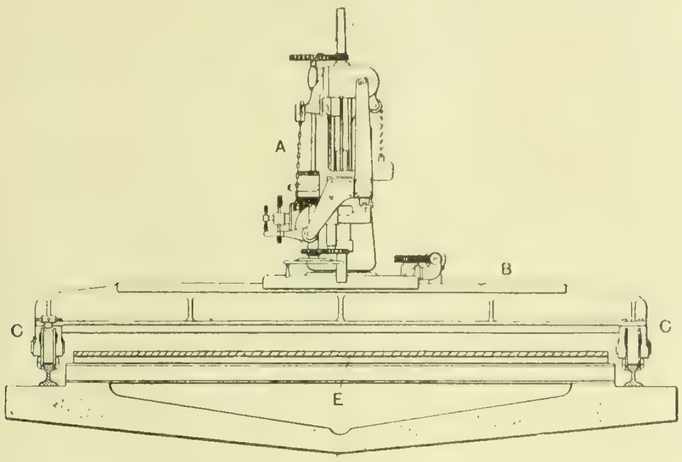


FIG. 1.

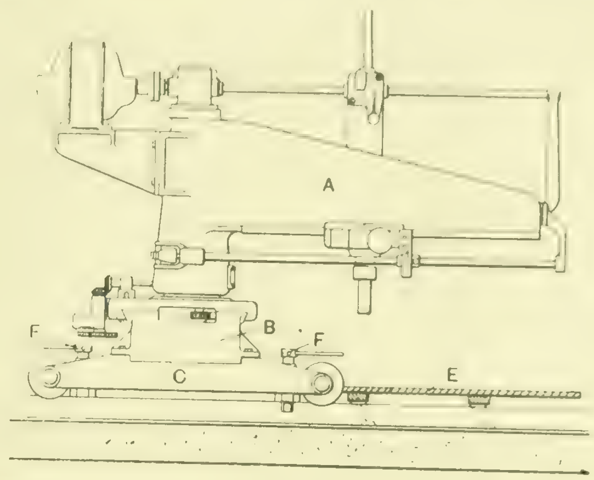


FIG. 2.

ASQUITH'S DRILLING MACHINE.

along the slide B. The latter is provided with an under carriage or bogey C to travel along rails. One or more locking devices F are provided for securing the cross slide B in any adjusted position along the rails during the drilling operation. The locking device comprises a pair of toggle levers, connected with a pair of bell crank levers and operated by a screw to cause the bell crank levers to grip the rail. The plate E to be drilled is supported on pieces of timber as shown. Referring to the diagram Fig. 3, the line 1 encloses a rectangular area any portion of which can be

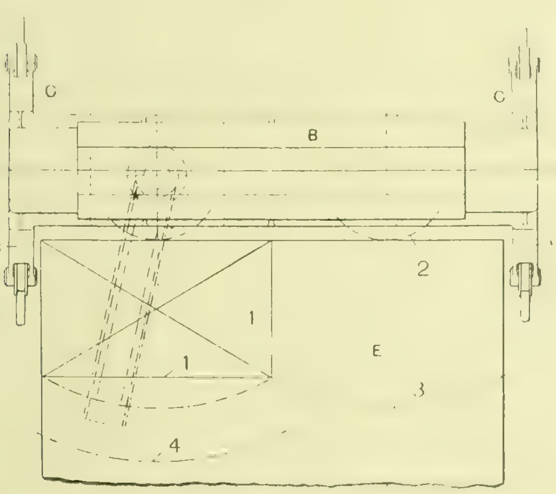


FIG. 3. ASQUITH'S DRILLING MACHINE.

drilled at one setting, the broken lines 2 and 3 represent the minimum and maximum radii that can be described by the drill, and the broken line 4 represents the amount of clearance to be allowed to enable the drill to work through the maximum radius. With this tool, which has been designed and patented by Messrs. William Asquith, Ltd., Highroad Well Works, Halifax, holes can be drilled in longitudinal, lateral, and diagonal rows and also in curved rows at one setting of the plate, and owing to the cross slide bed being capable of being traversed along the rails, a comparatively short radial arm can be employed for drilling a comparatively wide plate.

WORM AND WORM WHEEL DRIVES.*

BY E. J. LEES.

WHEN discussing worms and wheels, it is necessary to refer to certain factors which enter into their design and manufacture. In order to be clear these terms are illustrated and defined, all of them being in connection with the straight or cylindrical worm.

Circular Pitch. The distance between the centre of one tooth and the centre of the next measured on the pitch line, parallel to the axis when speaking of the worm, and at right angles to the axis when speaking of the wheel.

Normal Pitch. The distance from the centre of one teeth to the centre of the next, measured at right angles to the angle of the teeth or thread, which is also the shortest distance between centres of teeth.

Lead of a Worm. The advance of one thread in one complete revolution of the worm measured parallel to its axis.

Angle of a Worm. The angle of the thread measured from a right angle to its axis.

Pressure Angle of Worm Thread. The inclination of one side of the thread measured from a perpendicular at right angles to the axis.

Papers have been written regarding the theory, and numerous tests have been made which prove that if properly mounted, and all materials, lubrication, &c., are as nearly correct as obtainable, an efficiency of 93 per cent. is possible, while claims are made for even higher efficiencies. In view of this, it would seem best not to go into the same paths of investigation further than necessary, but to bring out, if possible, other vital points which are incidental not only to the design, but also to the manufacture.

Reviewing some of the papers and tests above mentioned, we find in "Worm and Spiral Gearing," by F. A. Halsey, the statement that worms with slight angles of thread below 9 were a failure and those above 12½° were successful. He quotes James Christie, of the Pencoyd Iron Works, suggesting as a good rule that successful worms begin with those having the lead equal to the pitch diameter giving an angle of 17° and 15′. Mr. Halsey also gives examples where worms of large diameters were failures, but when changed to smaller diameters were successful. This is attributed to reduction of pitch velocity and an increase of angle. He mentions that most worms are successful at 200ft. pitch velocity, but cases have been known where 800ft. were used. Regarding the thread angle, the maximum efficiency would be at 43° and 34′, using 0·05 as the co-efficient of friction.

In "Page's Magazine" for November, 1903, page 428, there is an interesting article in regard to the worms and wheels used by the Oerlikon Company, and also a table giving efficiencies which are very interesting. Quoting from the article: "The efficiency increases with the angle of inclination up to a certain point with the smallness of the co-efficient of friction, and knowing these two factors it is pos-

* Paper presented before the [illegible]

sible to calculate the theoretical efficiency as shown in the following table:

Table of Worm Efficiency.

Co-efficient of friction.	Angle of Inclination.								
	5°	10°	15°	20°	25°	30°	35°	40°	45°
0·01	89·7	94·5	96·1	97·0	97·4	97·7	97·9	98·0	98·0
0·02	81·3	89·5	92·6	94·1	95·0	95·5	95·9	96·0	96·1
0·03	74·3	85·0	89·2	91·4	92·7	93·4	93·9	94·1	94·2
0·04	68·4	80·9	86·1	88·8	90·4	91·4	92·0	92·2	92·3
0·05	63·4	77·2	83·1	86·3	88·2	89·4	90·1	90·4	90·5
0·06	59·0	73·8	80·4	84·0	86·1	87·5	88·2	88·6	88·7
0·07	55·2	70·7	77·8	81·7	84·1	85·6	86·4	86·9	86·9
0·08	51·9	67·8	75·4	79·6	82·2	83·8	84·7	85·2	85·2
0·09	48·9	65·2	73·1	77·6	80·3	82·0	83·0	83·5	83·5
0·10	46·3	62·7	70·9	75·6	78·5	80·3	81·4	81·9	81·8

"Experience shows that for larger angles of inclination than 25° to 30° the efficiency increases very little, especially

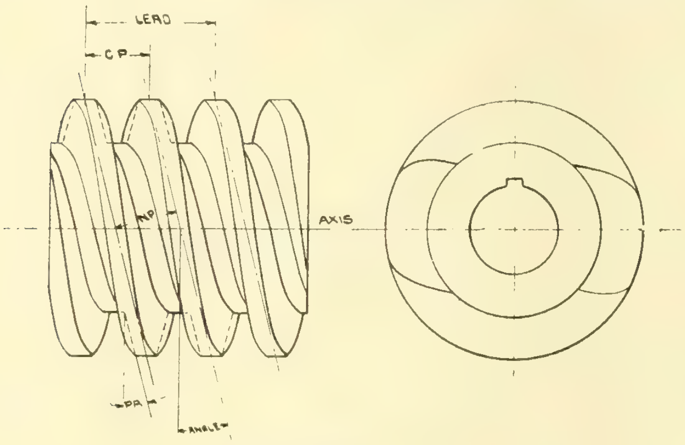


Fig. 1.—Worm Definitions.

if the co-efficient of friction be small, and this fact is of importance in practice because, for reasons of gear ratio and conditions of a constructive nature, an angle greater than 30° cannot be employed. The co-efficient of friction increases with the load and diminishes to a certain extent with increase of speed. Besides the friction between the worm and wheel teeth, there is also the friction of the spindle bearings and the ball bearings for taking the axial thrust. To obtain the best results, there must be very careful choice of dimensions of teeth, of the stresses between them, and the angle of inclination.

"To show what can be done, the following are the results of a test with an Oerlikon worm gear for a colliery winding engine: The motor gave 30 to 40 b.h.p. at 780 revs. The normal load was 25 b.h.p., but at starting it can develop 40 b.h.p. The worm gear ratio is 13·6 to 1, the helicoidal bronze wheel having 68 teeth and the worm five threads. The efficiency at one-third normal load gave 90 per cent., at full load 94½ per cent., and at 50 per cent. overload 93 per cent."

At the annual meeting of the A.S.M.E. in 1912, Wm. A. Kenerson presented a paper entitled "Investigation of Efficiency of Worm Gearing for Automobile Transmission." This investigation was made at the plant of the Brown & Sharpe Manufacturing Company. The illustrations show that the worm and wheel were both mounted in a case with ball bearings for both shafts and for end thrust, the end thrust having double spherical seated ball bearings. The diagrams show an extremely high efficiency in this test, in some cases up to 97·9 per cent.

At the Ingersoll Milling Machine Company's plant at Rockford, Ill., worms and wheels have been successfully used with dimensions as follows: Worms 5½in. outside diameter, 1¼in. circular pitch, 4 threads, 5in. lead, angle of 18° and 26′, pressure 14½°, the depth of tooth conforming to the normal pitch, which is 1·186in., making the whole depth of tooth about ¾in.; wheels have 50 teeth, some of which are made of bronze of the following composition:—

Copper	84·00
Tin	12·52
Lead	2·205
Zinc	1·24
Phosphorus	0·035

These worms of steel and wheels of bronze have been driving the horizontal cutter spindles of a large milling machine in this plant for the last 14 years without being replaced. One of the steel worms and a cast-iron worm wheel have been operating a large screw press for broaching and inserting teeth in the milling cutters which they manufacture. The pulley on the worm is 18in. diam. and has a 10in. driving belt. This drive has been in continuous use 17 years and the worm wheel still seems to be in good condition. In regard to the ball-bearing thrusts for these drives, there was considerable trouble at the start owing to the use of a flat single ball bearing, but later the double race and double spherically-seated bearing which is now so successful was developed.

From the above it is reasonable to assume that a worm with a thread angle of from 17° to 43° would be successful, but there is one feature that must be taken into consideration, and that is the pressure angle of the thread. As the number of threads used in the worm is increased to get more lead and, therefore, more angle of thread, the pressure angle of the tooth should also be increased. If this is not done, the peculiar warped nature of the worm will not allow sufficient of the wheel to intersect with its teeth and will undercut them with a consequent loss of surface contact, which contact should be as great as possible.

Consider a blank with rings on it, then a thread; now add other threads, and the angle of thread will gradually increase until at a maximum we have a spur pinion, threads or teeth having changed 90°, and at either extreme, it is quite apparent that there will be no efficiency in a line parallel with the axis; in regard to tooth contact, it is clear that as the threads increase the action between the worm and the wheel will be less until at the extreme or spur pinion all the teeth will be cut away in the wheel. Because the action between the worm and the wheel teeth is largely sliding, it stands to reason that the area of contact in these teeth is

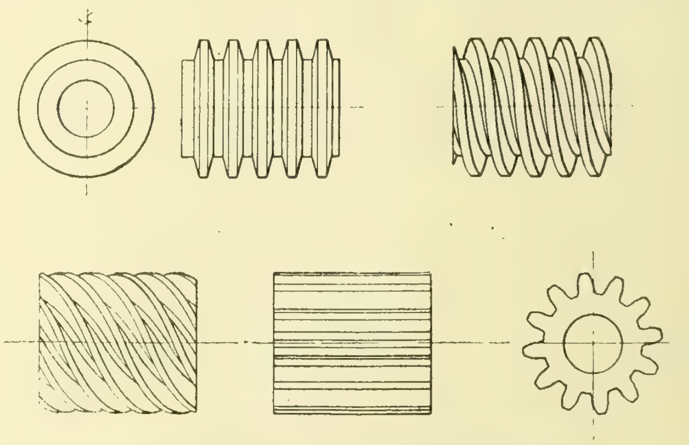


Fig. 2.—Diagram showing Change from Rings to Spur Pinion.

governed to a large extent by the ratio, which is controlled by the number of threads in the worm. And if an efficient angle be used, the width of face of the wheel must be narrower as the angle increases; this statement is made assuming the wheel to conform to the worm and be made by the process known as hobbing. If the face be made too wide, the hob will cut away the ends of the teeth on the wheel to a point, but the greater pressure angle will eliminate this to some extent and allow more width and, therefore, more surface contact. To my mind, the correct surface contact of the teeth in a worm and wheel is a most vital point, and a correct design may be spoiled by incorrect contact of the teeth, due to error in their manufacture and assembly.

In gearing in general, eccentricity is one of the great sources of trouble; this must be guarded against in making

the worm, the wheel, and especially the hob. The worm-wheel must not only run true on its pitch diameter, but must be bored perfectly true, and not run out sideways. Designers may differ as to the form of tooth to use, but regardless of what form is used, the best results will be obtained by making the hob in identically the same manner as the worm is to be made; that is as far as the tooth form is concerned. After this outline is obtained, of course, the hob may be relieved, but the relieving tool should be made to conform to the thread as made on the worm, working to the normal section. I mention this because so many hobs are ordered from a cutter-maker who makes a relieving tool for a lathe according to his own ideas, and at the same time some shop is producing worms with threads that may or may not mesh correctly with a wheel cut with the hob. The above is true where an effort is made to obtain the maximum efficiency, but does not apply to very light loads and intermittent action.

As previously stated, the action of a worm and wheel, when transmitting power, is largely a sliding contact. For all good sliding surfaces used in machine tool construction, the two surfaces are scraped together, and as a rule have a liberal area. A worm and wheel, on the contrary, are subjected to extreme pressure and are very seldom scraped together. If the cost of production will allow, it is a good plan to make the worm as perfect as possible, relative to concentricity and uniformity of teeth in size and indexing, with a very smooth surface after hardening which, even if ground, should then be polished. Mate the worm and wheel together in a fixture that will allow a centre adjustment, and scrape the bronze wheel to conform to the worm, using the regular methods of red-leading or blueing the thread of the worm to find the contact on the teeth of the wheel to be scraped. The above appears to be a refinement which will be very expensive, but when one considers the cost of inspecting, grinding in, and other precautions used in comparison, it is probably not so extreme as it may at first appear, for it has the advantage of being successful, is based on contact with a worm where the outline can be defined, and if these worms are exact duplicates, is interchangeable, a thing that is an absolute impossibility by any method of lapping or grinding where two surfaces are allowed to change indiscriminately in the process.

The need of the interchangeability of parts manufactured in the modern shops to-day has resulted in the development of manufacturing operations to extreme limits, measuring and testing machines, and the education of mechanics who are capable of producing to these limits, so that to-day we find a machine so delicate and accurate that it will measure the balls used in a ball bearing to fractions of a thousandth of an inch, and ball races being ground so accurately that all the balls do their share of the work and, therefore, make the ball thrust a success, where formerly it was condemned on account of a ball crushing. When it is understood that the balls varied in diameter and were placed in supposedly parallel bearings, that when the large ball came to the tight side of the ball race, it alone had to take all the thrust, the reason why it either crushed or scored the ball race is apparent. Now that balls are made uniform and double spherical seats are used for the races, this trouble is eliminated.

The question might consistently be asked at this point, why the spherical seat if the machine work and the balls are accurate? The answer is that the burden of accuracy is constantly changing, and at the present time it is largely up to the material used. The strenuous work the mechanism is subjected to will often create a flexibility that must be taken care of. This brings us to the shafts on which the worm and the wheel are mounted; the ball bearings used here should be of the self-aligning type, which will readily take care of alignment and give flexibility.

Quoting from a ball-bearing authority: "Ten years ago anyone who advocated ball bearings as a means of avoiding breakdowns on machinery would have met with strong opposition, and it may well be admitted that the objections which were raised at that time against the use of ball bearings in many industrial applications were in some measure justified. It was argued that ball bearings, having to be made from steel hardened to the highest degree, would be extremely brittle and liable to fracture. The general feature of construction and the processes of manufacture had not attained the degree of excellence to which ball bearings are now being produced for a practically unlimited field of application, in a wide range of types and sizes, and for a variety of load conditions, speeds, and purposes. While results from some of the earlier ball bearings tended to promote the industry, many failures checked its progress; but years of research, experiment, and painstaking developments in processes of manufacture have served to overcome old prejudices."

At one of the leading automobile factories I found the following interesting features: They manufacture their own ball bearings; that is, they make all the bearings and buy the balls to use in them. These balls pass through a most rigid inspection, both for diameter and smoothness of surface. They use a measuring machine called the minimeter, which is graduated to measure $\frac{1}{500}$mm., and by dividing the graduations the reading would give $\frac{1}{1000}$ mm., which is about $\frac{1}{25000}$in. This same machine will check on the surface of a ball whether or not it has a smooth finish, and it is remarkable what a difference there is when rolling a perfectly smooth ball under this measuring indicator and then substituting

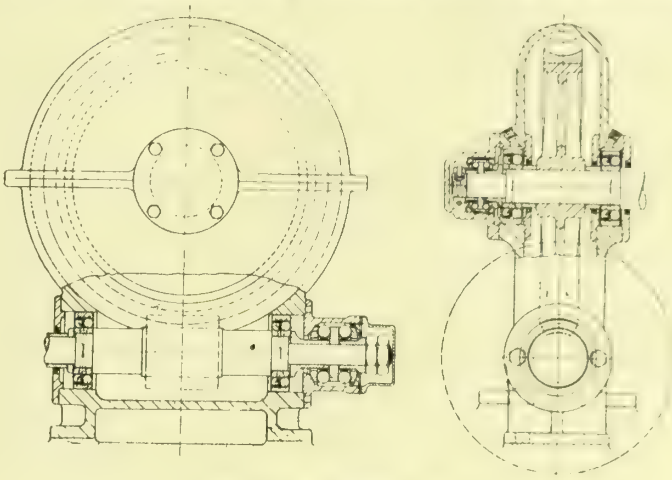


FIG. 3.—WORM WHEEL CASE.

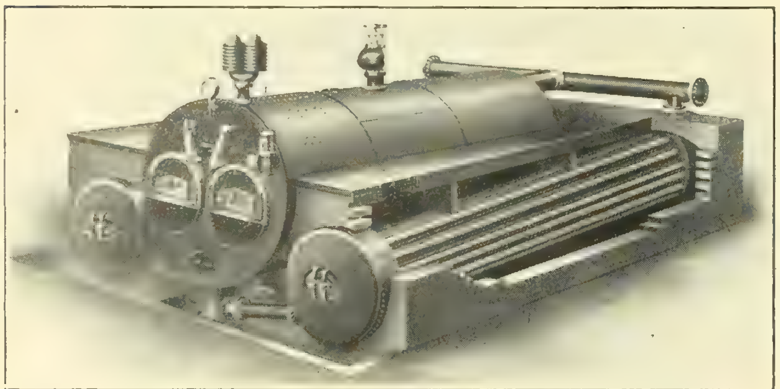
one that is apparently all right, but which the minimeter condemns because of surface roughness. Magnifying glasses are used for detecting irregularities on the surface; these glasses magnify from 65 to 125 diameters.

The balls have to pass inspection to a limit of $\frac{1}{10000}$in. diam.; that is, all the balls to go in one race must be within this limit. The inner and outer ball races are ground so that when the bearings are assembled, the space in which the ball is to run is about one-quarter to one-half thousandth of an inch larger than the ball. Experience has shown that a ball bearing made this way is more liable to give satisfaction than an adjustable ball bearing with a screw take-up which some inexperienced mechanic might adjust either too tightly or too loosely, and thus destroy its life and efficiency. As a startling illustration of ball-bearing efficiency, there is a machine for roughing out the ball races internally which has all its shafts and movements and emery wheel spindle mounted on ball bearings. This machine, with the same belt speed and power applied, will rough out just twice the amount of bearings a day that formerly were made on similar machines with plain bearings. It is very evident that the ball bearing is destined to be a most important factor in the success of the worm and wheel as a drive.

In summing up, I will say that from all indications the worm and wheel as a drive will become more popular and more successful when it is thoroughly understood that all the factors which enter into its design and manufacture must be carefully looked into. There is certainly no doubt that the manufacturers of machine tools are doing their part to make machines which, if handled properly, will produce down to limits of extreme accuracy. The ball bearings which are now on the market meet the requirements demanded of them, while the measuring machines are capable of measuring down finer than required.

THE HUDSON COMBINED CYLINDRICAL AND WATER-TUBE BOILER.

THE accompanying illustration shows the "Hudson" patent cylindrical and water-tube boiler, which has been designed with a view to combine the advantages of the water tube and cylindrical types in one unit. The general design of the boiler will be evident from a perusal of the illustration. It consists essentially of a shortened Lancashire or Cornish boiler, in the side flues of which are arranged the water-tube elements. The tubes are expanded into headers at each end, and are given a rise from the front to the back of the boiler. The two front headers are connected by means of pipes to a well fitted to the base of the cylindrical boiler, and the two back headers to an overhead cross pipe which communicates with the steam space of the cylindrical boiler. These two back headers are further united at the back end by a second tee-shaped pipe which enters the boiler at the level of the top of the furnace flues and balances the water level in the three elements. The overhead cross pipe collects the steam from the two rear headers of the water-tube elements, and conducts it to the steam space of the cylindrical boiler. The feed water is introduced at the front ends of the cylindrical element, and is carried forward in an internal pipe for about 8 feet. By this means the water is raised to a high temperature, and any scale-forming matter is precipitated before entering the water tubes. Further, a uniform temperature is maintained from top to bottom of the cylindrical element, which secures equal expansion of shell



THE HUDSON COMBINED CYLINDRICAL AND WATER-TUBE BOILER.

and furnaces, and thus prevents grooving. The gases, after leaving the furnace tubes, pass along the water-tube elements, then along the bottom of the shell, and thence to the chimney. The boiler is easily accessible for cleaning and inspection purposes, and occupies a minimum of space, requiring only about half that necessary for Lancashire boilers of equivalent evaporation, while the head room is the same in both cases.

The boiler, which is manufactured by Messrs. Thomas Hudson, Ltd., Sheepford Boiler Works, Coatbridge, is made in sizes covering a range of evaporation from 3,000lbs. to 20,000lbs. of water per hour. For evaporations up to 8,000lbs. of water per hour, the cylindrical element of the boiler is of the Cornish type. The standard type of Hudson boiler has a cylindrical element 16ft. long by 8ft. diam., a heating surface of 2,100 sq. ft., and an economical range of evaporation from 8,000lbs. to 15,000lbs. of water per hour. The evaporation per square foot of heating surface is 7½lbs., using a good-quality of fuel and a chimney draught of about ⅝in. An evaporative test on one of these standard boilers, hand fired and without the use of an economiser or superheater, at the works of Messrs. James Dunlop & Co., Ltd., Calderbank Steel Works, was undertaken by the Scottish Boiler Insurance and Engine Inspection Company, Ltd., with the following results:—

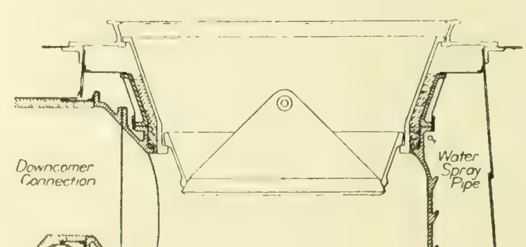
Weight of feed water per hour	15,280lbs.
Temperature of feed to boiler	145° Fah.
Gauge pressure	66lbs. per sq. in.
Absolute pressure	80·85lbs. per sq. in.
Total moisture in the steam	·036 per lb.
Temperature of saturation	312° Fah.

	B.T.U.	Per cent.
Total heat value of 1lb. of dried fuel	11,606	—
Heat transferred to water (thermal efficiency)	8,652	74·6
Heat carried away by products of combustion	1,886	16·2
Heat carried away by excess of air	707	6·1
Heat lost in evaporating and superheating moisture mixed with fuel	138	1·19
Heat lost by incomplete combustion	—	
Heat lost by unburnt carbon in ash	183	1·57
Balance of heat account, errors in observation and unmeasured losses such as—those due to radiation, escape of unburnt hydrocarbons, superheating moisture in air, loss in hot ashes, &c. (by difference)	40	0·33
	11,606	99·99

Heat transmitted per sq. ft. of heating surface per hour	8,515 B.Th.U.
Weight of fuel fired per sq. ft. of grate per hour	45·8lbs.
Weight of dried fuel fired per sq. ft. of grate per hour	41·2lbs.
Water evaporated per lb. of fuel as fired	7·5lbs.
Equivalent evaporation from and at 212° Fah. per lb. of fuel as fired	8·2lbs.
Water evaporated per lb. of dried fuel	8·4lbs.
Equivalent evaporation per lb. of dried fuel from and at 212° Fah.	9·2lbs.
Equivalent evaporation per lb. of carbon value of fuel from and at 212° Fah.	11·6lbs.
Weight of feed from and at 212° Fah. per sq. ft. of heating surface per hour	9·0lbs.
Air used per lb. of dried fuel	16·2lbs.
Ratio of air used to air theoretically needed	1·39lbs.

A BLASTFURNACE STOCK LINE SHIELD.

MANY devices have been suggested for protecting the inwall of a blastfurnace in the vicinity of the stock line. One arrangement which has given satisfactory results is shown in the illustration. This device has been patented by Frank C. Roberts, Philadelphia, and Albert Broden, blastfurnace superintendent of the Reading Iron Company. As indicated, the usual brick inwall is displaced for a distance of 16ft. below the top of the furnace by a cylindrical metal casing supported from below by the outer metal shell of the furnace. The metal casing is arranged to support only its own weight. The charging hopper, &c., are carried independently by the furnace shell. The upper end of the metal



METAL SHIELD FOR PROTECTING THE INWALL OF A BLASTFURNACE.

casing is secured to the furnace shell by an annular wrought-metal diaphragm, designed to allow for the vertical expansion of the casing and to prevent the escape of gas from the furnace. A circular spray pipe and distributing troughs are located on the outside of the central part of the casing to permit of external water cooling. Protection of the upper end of the brick inwall is afforded by castings containing coils of pipe, through which water is circulated, also by water

pockets which accumulate the water of the cooling system before it overflows to the waste. The gas downcomer is connected to the casing by a flanged joint so designed that the casing may expand vertically without disturbing the downcomer. The entire casing is made of steel castings except the upper ring which is cast iron. The casing is heavily ribbed and banded. A series of openings are provided through the furnace shell around the bottom and the top of the casing; a rapid air circulation takes place through these openings and over the casing. The experience of the Reading Iron Company has demonstrated that air cooling is sufficient under ordinary conditions, and that water cooling is only necessary in emergencies. It is essential, however, to circulate water continuously through the coil casting that protects the upper part of the inwall. The company's experience with this design of protection has been so satisfactory that it has recently contracted for a similar equipment for its Crumwold furnace at Emaus, Pa.

INDUSTRIAL AND TRADE NOTES.

British Trade in China.—The President of the Board of Trade, on the recommendation of the Advisory Committee on Commercial Intelligence, has appointed Mr. T. M. Ainscough to be a Special Commissioner to enquire into the conditions and prospects of British trade in China. Firms desirous of communicating with Mr. Ainscough on the subject of his mission should address letters to him care of the Commercial Intelligence Branch of the Board of Trade, 73, Basinghall Street, London, E.C. Mr. Ainscough will leave England before the end of the present month.

Light Railway.—The Board of Trade have recently confirmed the under-mentioned Order made by the Light Railway Commissioners: North Staffordshire Railway (Trentham, Newcastle-under-Lyme, and Silverdale Light Railways) Order, 1914, authorising the construction of light railways in the county of Stafford, from Trentham to Newcastle-under-Lyme and Silverdale, with the reconstruction and working of certain branch railways of the North Staffordshire Railway Company as light railways under the Light Railways Acts, 1896 and 1912, and for other purposes.

Results of a Profit-sharing Plan.—The "Engineering News" gives some particulars of a profit-sharing scheme put into operation at the beginning of 1913 by the Clipper Belt Lacer Company, Grand Rapids, Mich. The plan actually used had been tried out with success the year before in one department. The scheme is very simple—the factory has been put on piecework basis with an agreement never to lower the piece rate; at the end of each year all employés who have been with the company one year or less receive 5 per cent. of their annual wages, this percentage rising 1 per cent. for each year of service up to a maximum rate of 10 per cent. The plan is contingent on sufficient profits of the concern. At the end of 1913 it was found that $3,000 was available for distribution; two persons received the 10 per cent. maximum. The yearly output was doubled with slight increase in force; the unit cost of product was reduced 9 per cent. and the average gain to employés (over old day wages) was 19 per cent. The plan is to be continued.

Locomotive Tenders: Successful German Competition.—In a recent discussion in the South African Union Parliament the Minister of Railways, in reply to a question as to whether it was the case that a large order for locomotives and coaches had been placed in Germany, said that orders for 10 locomotives and for 34 coaches of different types had been recently placed in Germany. The locomotive tender accepted was at £5,160 per engine f.o.b. Hamburg, and the price was subsequently increased to £5,262 owing to amendments made in the specification. The Minister quoted the tenders of unsuccessful competitors for locomotives and coaches. Of these one British firm tendered £6,515 f.o.b. Glasgow; the prices of other British firms ranging from the last-named figure to £7,190. The lowest British tender was £6,515 per engine f.o.b. Glasgow. The difference for ten engines was £13,550. As to the coaches, the Minister stated that the tenders included the following: A continental firm, £80,948 f.o.b. Antwerp; an American firm, £81,724 f.o.b. New York; a British firm, £82,100 f.o.b. Mersey; a continental firm, £82,510 f.o.b. Hamburg; another British firm, £83,525 f.o.b. Birkenhead; and then there were tenders ranging to British firms which quoted £96,476 f.o.b. Birkenhead. The lowest British tender was £82,100 f.o.b. Mersey; the tender accepted was £60,403 f.o.b. Hamburg, the difference being £21,697.

Trade Circulars and Catalogues.—We have received from R. S. Price, Ltd., 12, Norfolk Street, London, W.C., illustrated particulars of the Iona steam turbine, which is designed to meet the demand for small powers from ½ h.p. and upwards, running at suitable speeds for direct coupling to fans, pressure blowers, and centrifugal pumps. The turbine is of the one-pressure step multi-velocity stage type with reversed axial flow, the steam expanding adiabatically in the nozzles from the initial pressure of the stop valve down to the exhaust pressure, after the principle of the Laval machine. From Chas. Taylor, Bartholomew Street, Birmingham, catalogue of rotary cutting-off machines for dealing with bars, tubes, &c. The machines are made in various sizes up to as large as 8in. in diameter. From the Baldwin Locomotive Works, Philadelphia, an illustrated bulletin, giving particulars of types of logging locomotives which are constructed for special classes of service in the logging industry, where steep grades, sharp curves, and uneven track are often pronounced features. The locomotives are made for a variety of gauges, and include nearly all classes of wheel base, and also others of the geared truck type. From W. Grepel & Co., St. Thomas Street, London, S.E., a wall card giving particulars of aluminium conductors with minute details of area, resistance, weight, &c.

A Plea for Nationalisation of Railways.—Mr. Emil Davies, chairman of the Railway Nationalisation Society, giving evidence before the Royal Commission on Railways, said there were some services which, from their nature, had come to be regarded as being distinct from ordinary commercial undertakings, in that they should be operated primarily to serve social needs. He contended that railways were one of these services. The nationalisation of railways would, he said, lead to uniformity of charges. In every European country where the railways were worked by the State there was one uniform charge over the whole system. In the United Kingdom there was no uniformity. He estimated that to nationalise the railways in this country, at 25 years' purchase, it would be necessary to issue 3 per cent. stock of the value of £973,000,000. This would mean that the State would issue stock bearing interest of £32,000,000, and acquire property bringing in a profit of £52,000,000. Witness further stated that he estimated that the nationalisation of the railways would result in a saving of £10,000,000 a year in working expenses, as "there is such a tremendous waste going on now." With regard to season tickets the witness said several countries issued tickets over the whole national system, the cost of which was less than that of a season ticket between Manchester and London. The ordinary fares on the European State-owned railways were 50 per cent. less than on the British railways. Nationalisation would mean a regular mileage rate all over.

The Use of Pumping Machinery in Egypt.—According to the April issue of the "Journal" of the British Chamber of Commerce of Egypt, there has lately been an exceedingly heavy demand for all classes of pumping machinery in Egypt, owing to the low level of the last Nile flood and to the certainty that there would be a short supply of water this spring. The Government has generally refused to allow pumps to be set up either on the banks of the Nile or canals. Numerous artesian wells have, accordingly, been sunk, entailing heavy imports of galvanised wrought iron pipes, and the demand for small pumps has also been accentuated by a shortage of draught animals. Importers of machinery have been quite unable to keep pace with the demand; local stocks were soon exhausted, and the normal advance requirements for the season were ear-marked in advance for purchasers. Exceedingly heavy repeat orders were placed with the principal manufacturers, and intending buyers have found it difficult, if not impossible, to obtain delivery. The business has not been confined to one class of engine, but has included pumps driven by steam, semi-Diesel, and oil engines, and also producer gas engines. The size of the units most in demand varies from 10 b.h.p. to 36 b.h.p. for the oil engines, 6 h.p. to 10 h.p. for single cylinder steam engines, and 8 h.p. to 16 h.p. for compound steam engines. The usual lift is through a head varying from 40ft. to 50ft. The sizes of the pipes used for the artesian wells are 6in. and 8in., drilled and undrilled. It is not likely that the demand for artesian wells and pumps will continue to be so keen as during the last few months, but the native cultivator is becoming enlightened as to the advantages of being able to fall back on underground water when the supply from the river is short, and there should continue to be a steady development in this direction.

Contracts for Electrical Work.—The Institution of Electrical Engineers has issued a form of model general conditions recommended for use in connection with contracts for electrical works. The conditions are revised to April, 1914, and can be obtained from the Institution, at one shilling.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1913.

Furnaces and fuel feeding devices therefor. Greenstreet. 1515.
Conveyers and elevators. Taylor. 2761.
Friction clutches. Shiner. 6552.
Vices and cramps. Lawrence & Alexander. 8898.
Rail grinding or surfacing machines. Woods. 9007.
Carburetters for internal combustion engines. Soc. M. Goudard et Mennesson. 9145.
System of burning liquid fuel in locomotive boilers. Laing. 9265.
Temperature regulators. Soc. Anon. des Etablissements Delannay Belleville. 9269.
Driving or conveyer belts. Turner & Turner. 9309.
Turbine engines. Kalvelage. 9341.
Piston valves for pumps. James Simpson & Co., and Shrimpton. 9350.
Grinding machines. Dickinson. 9382.
Cam operated valves for internal combustion engines. James and Robertson. 9419.
Gas turbines. Churchill-Shann. 9454.
Carburetters for internal combustion engines. Gornall. 9629.
Check or non return valves. Allgemeine Elektricitats Ges. 9766.
Pulley blocks. Clarke. 9780.
Overwind prevention gear for colliery winding engines. Smith. 9840.
Turbine installations. Fottinger. 9997.
Starters for internal combustion engines. Birch. 10003.
Conveying apparatus. Clark & Warman. 10151.
Connecting rods for radial cylinder motors. Soc. Anon. des Moteurs Martin. 10155.
Internal-combustion engines. De Walden & Thomas. 10769.
Engine or machine packings. Beldam. 11562.
Gravity conveyers. British Mathews, Ltd., Barton & Barton. 11610.
Carburetters of internal combustion engines. Openshaw. 13013.
Centrifugal pumps. Bertrams, Ltd., and Robertson. 13134.
Cylinders of internal combustion engines. Peel. 13670.
Speed indicators. Allemann. 13885.
Trip gear for winding engines. Morton & Morton. 14005.
Spanners and wrenches. Wallace. 14360.
Reversible regenerative gas furnaces of the Siemens type. Reynolds. 14541.
Endless band grinding and polishing machine. Townsend and Turner. 15805.
Starting arrangement for internal-combustion engines. Higginbotham. 16206.
Ovens for generating gas and producing coke. Koppers. 16318.
Manufacture of lubricating grease. Haddan. 16480.
Carburetters for internal-combustion engines. Tricoche. 16843.
Water-cooling device for internal-combustion engines. Brown and Holland. 17002.
Apparatus for automatically indicating and recording the combined efficiency of a steam motor and coupled electrical generator. Xenaky & Gilman. 17066.
Adjustable double acting rotary pump. Parkes. 17740.
Methods of lubricating internal-combustion engines. Douglas. 17744.
Systems for raising water or other liquids, and for obtaining motive power. Piazza. 19087.
Ore reducing machines. Wade. 19301.
Valves. Williams. 21355.
Device for relieving or cleansing pump valves. Evans. 21504.
Turret lathes. Herbert & Vernon. 21639.
Rotary air pumps for surface condensers. Soc. Anon. pour l'Exploitation des procedes Westinghouse-Leblanc. 21690.
Signalling and controlling locomotives. Partington. 22386.
Fixing of turbine blades. Uffelmann & Baily 22740.
Locking bolts. Gotze. 23426.
Grease cup. Sauser. 24581.
Jig conveyers. Peisen. 26177.
Internal combustion engines and pumps. Court. 26674.
Bolts. Gould & Courtway. 26999.
Poppet inlet valves of internal combustion engines. Westbury. 27527.
Railway rail joints. Slater. 27640.
Method of working pure iron. Carnahan. 28571.
Non return starting handle for explosion engines Lecocq and Van der Aa. 28618.
Steam superheaters. Gordon & Sanderson. 28809.
Injectors. Gresham & Gresham. 29328.
Oil pumps for motors. Cyklon Maschinenfabrik Ges. 29564.
High pressure gas generators. Palmer. 29669.
Combustion chambers of internal combustion engines. Laurin. 29811.

1914.

Wire rope clamp. Eddelbuttel Reimers. 1749.
Feed mechanism for drilling machines. Herbert & Vernon. 3779.
Rotors for dynamos and cooling arrangements for the same. Siemens Schuckertwerke Ges. 5828.

ELECTRICAL, 1912.

Arc lamps. Weiss. 24243.

1913.

Telephony. Hulfish. 4071.
Thermostats for controlling electric circuits Prim & Roper. 9140.
Automatic telephones. Furnival. 9205.
Electric switches. British Thomson-Houston Company. 9384.
Telephone systems. Automatic Telephone Manufacturing Company. 9593.
Telegraphy. Judd, Davies, and Eastern Telegraph Company. 9768.
Control of electro-mechanical transmission gear. Haworth. 9996.
Incandescent electric lamps. Beville. 10892.
Electrically operated or controlled valves. Irving & O'Donnell. 11623.
Electric starters for internal-combustion engines. Scott. 14742.
Electric switches for railways. Soc. d'Electricite Mors. 22127.
Brush or like sliding contacts for high-frequency electrical apparatus. Sorensen. 22176.
Generator of electricity for automobiles, forming a combined source of ignition and illumination. Sanchez & Baradat. 22228.
Brushes for electric contacts. Colas and Soc. d'Electricite "Nilmelior." 23754.
Electric batteries. De Mello. 24471.
Apparatus for electrically lighting road vehicles. Prior. 24898.
Telephone systems. Graham. 26287.
Flexible connections for electric conductors. Siemens Bros. Dynamo Works, Ltd. 29003.
Ventilation of dynamos. Siemens Bros. Dynamo Works, Ltd., and Kieffer.

1914.

Electrolytic meters. British Thomson-Houston Company. 2850.
Impulse transmitting mechanism for telephone systems. Hastings. 4082.

METAL QUOTATIONS.

TUESDAY, MAY 12TH.

Aluminium ingot	86/– per cwt.
,, wire, according to sizes, &c. ......from	107/4 ,,
,, sheets ,, ,, ... ,,	112/– ,,
Antimony	£27/–/– to £28/10/– per ton.
Brass, rolled	7⅛d. per lb.
,, tubes (brazed)	9⅝d. ,,
,, ,, (solid drawn)	7⅞d. ,,
,, ,, wire	7⅛d. ,,
Copper, Standard	£63/5/– per ton.
Iron, Cleveland	51/4½ ,,
,, Scotch	57/4½ ,,
Lead, English	£18/15/– ,,
,, Foreign (soft)	£18/7/6 ,,
Mica (in original cases), small	6d. to 3/– per lb.
,, ,, ,, medium	3/6 to 6/– ,,
,, ,, ,, large	7/6 to 11/– ,,
Quicksilver	£7/–/– per bottle.
Silver	26⅞d. per oz.
Spelter	£21/7/6 per ton.
Tin, block	£153/–/– per ton.
Tin plates, I.C.	12/7½ per box.
Zinc sheets (Silesian)	£24/10/– per ton.
,, (Stettin; Vieille Montagne)	£24/12/6 ,,

Explosion at an Ironworks.—A serious explosion occurred on the 8th inst., at the Ayresome Ironworks of Messrs. Gjers, Mills & Co., Middlesbrough, by which five labourers were more or less seriously injured. One of the furnaces, it is understood, was being put out of blast, when an unexpected fall of a portion of the contents of the furnace, which had been hanging, caused an explosion.

The Mechanical Engineer.
An Illustrated Weekly Journal
Vol. 33, No. 852.

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Telegrams: "Scientific," Manchester.
Telephone No. 6055 City.

SUBSCRIPTION RATES.

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Advertisements, displayed, for insertion in current issue should reach our Manchester office not later than first post Tuesday morning, and small prepaid advertisements not later than first post Wednesday morning.

Internal Strains in Cold-wrought Metals.

The May lecture delivered last week by Prof. E. Heyn to the Institute of Metals on the effects of internal strains in cold-wrought metals will be read with deep interest by all concerned with the use of metal for structural purposes. Prof. Heyn, who holds an important post at the Technical Institute, Charlottenburg, has made a lifelong study of the subject of stress and strain, and his paper is a classic. That serious internal stresses often exist in structural materials is known in a general way. Their existence is occasionally revealed by unexpected and puzzling fractures, and their possibility more or less allowed for by the factor which long usage has designated the "factor of safety," but which is sometimes humorously and more aptly described as the "factor of ignorance," for there is no doubt that if the engineer's knowledge of materials were more perfect, constructional ends could often be attained with greater economy and possibly greater safety. A good deal of attention has been directed during recent years to this object, and the metallurgist and the microscopist have in many ways shed a flood of light on the inner structure of metals and the play of forces that constitute strength or weakness. Though it is improbable that the nature of the primary forces which bind the molecules together will ever be thoroughly understood, the recession of the veil does add to our knowledge, and enables the engineer to practically measure and control them. Prof. Heyn's address was mainly concerned with the description of an ingenious method of analysis of the internal strains that exist in a plain cold-wrought metal which has been devised by him and Prof. Bauer, and as most structures are built of wrought or forged materials, the deductions are capable of much wider application.

That cold working of metals induces severe internal stresses is common experience, and it requires little thought

to realise that these internal stresses may be so serious in magnitude that the subsequent application of external forces of small amount, or even the persistent action of the internal stresses themselves, may result in fracture. The Rupert drop is a familiar illustration of the way in which material may be rendered unstable almost to the point of failure by internal stresses alone. These, which are produced by drops of molten glass falling in water, form a small tadpole-like structure, the outside of which sets and constitutes a hard shell, from which the interior endeavours to contract in vain, and which maintains its stability of form by the balance of tensile and compressive forces in the internal and external layers, respectively. So great are these forces that the rupture of the tail piece causes explosive collapse of the drop. The old type of blue glass water gauge is another example. All boiler attendants who have had experience with them may be aware that it frequently happened when a glass was renewed, several new ones might fracture in quick succession before one was found to stand. Though not generally known, the cause was pretty analogous to that of the Rupert drop. The outside of the tube, when manufactured, naturally cooled most rapidly, and formed a circular shell which prevented the inner core contracting as much as it otherwise would have done, and so set up in it a severe internal tensile stress. The magnitude of this depended on the rapidity of cooling, or, in other words, the amount of accommodation between the inner and outer shells of the tube, and it not infrequently happened that tubes carelessly made would shatter to pieces whilst lying in stock, as a result of the intense internal stress, or, if they did not do this, would fail as the result of some slight scratch on their inner surface, such as might be caused by drawing a bit of waste through it with wire to clean it, as a boiler attendant would naturally do, without suspecting what might follow. The "season cracking" of tubes made of brass and other copper alloys is a similar phenomena, which has often been discussed, and for which many mysterious theories have been propounded, though after Prof. Heyn's clear exposition of the origin of these failures most of the current theories will be consigned to the limbo of ignorance.

Whilst the existence of internal stresses has all along been recognised, Messrs. Heyn and Bauer are the first to devise a method of measuring them, and thus of acquiring exact knowledge. Without going into details, which, however, are described in the paper, and which we shall reproduce in full, it may be stated that the method consists in taking a test bar and carefully observing the changes in length between two points situated near the ends as successive layers are turned off. If the distance remains unchanged the bar is free from longitudinal internal stress, but if it alters it is as a consequence of the disturbance due to the movement of the material, and by simple mathematical reasoning the magnitude of the stresses can be deduced. The principle is simple, but the value of Prof. Heyn's paper lies in the valuable deductions made from actual tests, which we would commend to the careful perusal of all who are interested in the subject. The first case which gave the impetus to his researches was the cracking of some steam turbine blades, made of high per cent. nickel steel. The blades were of crescent section, and reduced to their final shape by cold drawing. Investigation of test bars of similar material by the method described revealed the extent to which internal stresses had been set up, especially in the neighbourhood of the sharp edges of the crescent section, where it was shown that the internal stresses were not much inferior to the ultimate tensile strength of the steel. Once an exact method of measuring internal stress is devised it is easy, of course, to make comparative observations of the effect of different treatments, such as hammering, rolling, drawing, annealing, &c., and the flood of light thrown on these is most instructive, not only to the research worker in the laboratory, but to the practical man who is more immediately concerned, or thinks he is, with the avoidance of troubles and defects than with the scientific reasons for them. The paper is another of the many striking illustrations which have been afforded during recent years of the way in which the scientific worker may be helpful to the practical constructive engineer.

TRIPLEX ARTICULATED LOCOMOTIVE FOR THE ERIE RAILROAD.

THE Baldwin Locomotive Works has recently completed for the Erie Railroad a locomotive for pusher service which develops a tractive force of 160,000lbs., and is by far the most powerful unit yet built. This capacity is secured, not by using excessive wheel-loads or a rigid wheel-base of unusual length, but by placing driving-wheels under the tender and thus making the weight of the latter available for adhesion. In heavy grade work especially, the weight of the tender detracts materially from the net hauling capacity of a locomotive of the usual type; while in this case the tender is used as a means for increasing the hauling capacity. We are indebted to our American contemporary, "The Railway Review," for the following particulars of this interesting locomotive, which has been built in accordance with patents granted to George R. Henderson, consulting engineer of the Baldwin Locomotive Works.

The wheel arrangement is 2-8-8-8-2, the third group of driving wheels and the rear truck being placed under the tender section. The six cylinders are all of the same size, two acting as high pressure and four as low pressure. The two high-pressure cylinders drive the middle group of wheels. The right-hand high-pressure cylinder exhausts into the two front cylinders, and the left-hand high-pressure cylinder exhausts into the two rear cylinders. This arrangement is therefore equivalent to a compound engine having a ratio of cylinder volumes of one to two.

The boiler has a conical connection in the middle of the barrel, and is fitted with the Gaines type of furnace. The firebox has a total length of 13ft. 6in., and of this the grates occupy 10ft. A combustion chamber 54in. long extends forward into the boiler barrel, and the tubes have a length of 24ft. The brick arch is supported on six 3½in. tubes, and heated air is delivered under the arch by seven 3in. pipes which are placed vertically in the bridge wall. There are two firedoors, placed 32½in. between centres, and a Street mechanical stoker is applied.

The barrel of this boiler measures 94in. diam. at the front end and 102½in. at the dome ring. The centre line is placed 10ft. 7in. above the rail. The circumferential seams are triple riveted, while the longitudinal seams have sextuple-riveted butt joints, which are welded at the ends, and have an efficiency equal to 90 per cent. of the solid plate. The dome is of pressed steel, 33in. diam. and 13in. high. It contains a Chambers' throttle, which is connected with the superheater header, in the usual manner, by an internal dry pipe. The superheater is composed of 53 elements, and is the largest ever applied to a locomotive, the superheating surface being 1,584 sq. ft. The header is divided, separate castings being used for the saturated and superheated steam sections. The front end contains a single exhaust nozzle, with a ring blower. The size of the nozzle can be varied by a simple adjusting device placed outside the smokebox. The stack is 22in. diam., and it has an internal section which extends down to the centre line of the boiler.

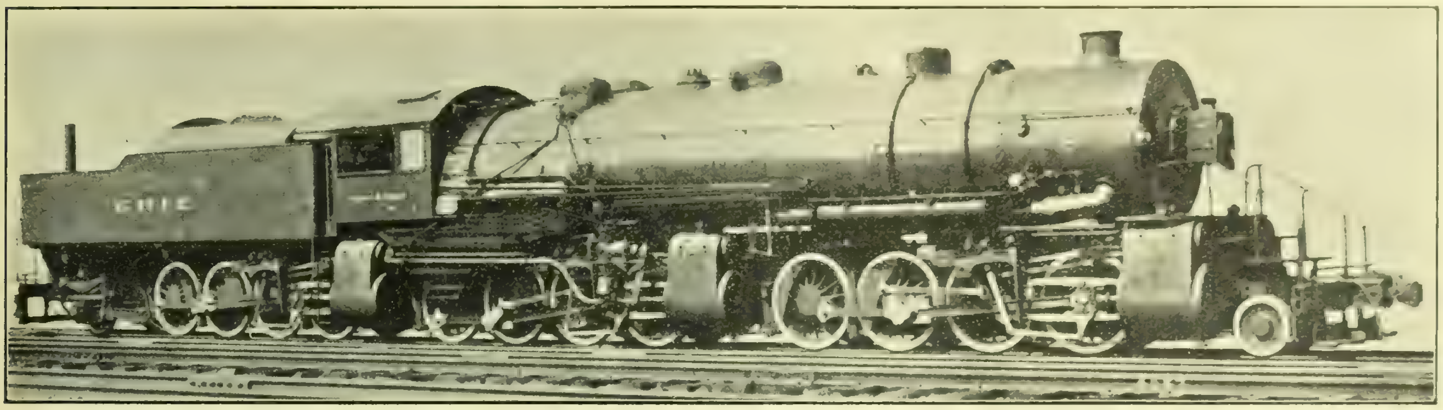
The superheated steam is conveyed to the high-pressure cylinders through outside pipes, and the high-pressure distri-

bution is controlled by 16in. piston valves, arranged for inside admission. Similar valves are applied to the low-pressure cylinders. These valves are all driven by Baker gears and the three sets of motions are controlled simultaneously by the Ragonnet power reverse mechanism. All six cylinders are cast from the same pattern, and the valve motion and driving gear details used with the three groups of wheels are as far as possible interchangeable. A large number of these details also interchange with those of the heavy Mikado type locomotives in service on this road.

Among the details of the driving gear may be mentioned the pistons, all six of which are alike. The piston heads are steel forgings, of dished shape, and each is surrounded by a cast-iron bull ring. The bull ring carries three packing rings, and is secured to the piston head by a retaining ring which is electrically welded into place. The cylinders and steam chests are bushed, and these bushings, as well as the piston and valve packing rings, are of Hunt-Spiller metal.

The pipes connecting the high and low-pressure cylinders are constructed like the flexible pipes in a Mallet locomotive. The arrangement of starting valve usually applied by the builders to Mallet locomotives is used on this engine, except that in the present case live steam is admitted to four low-pressure cylinders instead of two. The admission of steam is controlled by a manually operated valve in the cab.

This locomotive marks an interesting step in the development of heavy power for freight service. The efficiency of a locomotive for slow, heavy work is measured largely by the proportion of the total weight that is available for adhesion, and in this respect the present locomotive excels. About 90 per cent. of the total weight is carried on the driving wheels, as against approximately 65 per cent. in a Mallet locomotive of the 2-8-8-2 type, including, in the latter case, the weight of the separate tender. The leading features of this locomotive are indicated in the following table:—



TRIPLEX ARTICULATED LOCOMOTIVE FOR THE ERIE RAILROAD.

The high-pressure cylinder saddle has cored in it two passages, one of which conveys the exhaust from the right-hand cylinder to the front receiver pipe, while the other conveys the exhaust from the left-hand cylinder to the back receiver pipe. The front cylinders exhaust up the stack in the usual manner, while the exhaust from the rear cylinders is discharged up a pipe placed at the back end of the tank. Between the rear cylinders and the exhaust pipe is placed a feed-water heater, through which the exhaust steam passes. The heater consists of a long drum, traversed by small tubes. The drum has connection with the tank through a suitable valve, and the exhaust steam passes through the tubes. The hot feed from the drum is forced into the boiler by two pumps, which are driven from the crossheads of the high-pressure engine. Two injectors are also used, and they draw cold feed water from the front end of the tank. The pump and injector checks are placed on the top centre line of the boiler near the front end.

The tender section, as far as frames, wheels, equalisation, and driving gear are concerned, is arranged like a steam locomotive. The articulated connection between the middle and rear frames is placed under the cab, and between the rear cylinders. The radius bar on the middle frames makes a ball-jointed connection with the hinge pin. A similar connection is provided between the middle and front frames, and in this case the radius bar is pinned to the front frames in such a way as to allow vertical flexibility. The frames are vanadium steel castings, 6in. in width. Each is made in one piece with a single front section to which the cylinders and saddle are keyed and bolted. The front group of wheels is arranged with a continuous equalisation system, the leading truck being centre-bearing and equalised with the driving wheels as in a Consolidation engine. The second group of wheels has a continuous equalisation system on each side of the locomotive. In the rear group, the equalisation is broken between the second and third pairs of driving wheels. The rear truck, which is of the side-bearing type with outside journals, is equalised with the two rear pairs of driving wheels.

Type	2-8-8-8-2
Service	Pusher.
Cylinders (six)	36in by 32in.
Valves	16in. piston
Valve gears	Baker
Tractive power	160,000lbs.
Boiler, type	Conical
Min. diameter	94in
Working pressure	210lbs.
Firebox (Gaines), size	108in. by 162in
Grates, size	108in. by 120in.
Grate area	90 sq. ft.
Kind of fuel	Soft coal
Tubes, number and diameter	326—2¼in.
Flues, number and diameter	53—5½in.
Length	24ft.
Heating surface, firebox	272 sq. ft.
Combustion chamber	108 sq. ft.
Tubes and flues	6,418 sq. ft.
Arch tubes	88 sq. ft.
Total	6,886 sq. ft.
Superheating surface	1,584 sq. ft
Driving wheels, diameter	63in
Journals	11in. by 13 $\frac{1}{16}$ in.
Truck wheels, front, diameter	33½in.
Journals	6in. by 12in
Back, diameter	42in.
Journals	9in. by 14in
Weight on driving wheels, estimated	715,000lbs.
Total engine, estimated	830,000lbs
Wheel base, driving	71ft. 6in
Rigid, each group	16ft. 6in
Total	90ft.
Tender—	
Capacity, water	10.000 galls.
Capacity, coal	16 tons

Disastrous Explosion on a Liner.—Seven men were killed and several injured on the 12th inst., by an explosion in the engine room of the old Dominion liner, "Jefferson."

HIGH-POWER DIESEL ENGINES: THEIR DEVELOPMENT FOR MARINE SERVICE.*

BY JAMES RICHARDSON, B.SC., A.M.INST.C.E.

(Concluded from page 454.)

Compressors and Fuel Injection.—There is no doubt that with the Diesel oil engine the compressor required for the supply of the highly-compressed air necessary for the injection of the fuel has been a source of very considerable trouble, due to the conditions of continuous running imposed by marine service. These difficulties have been lessened by the substitution of 3-stage for 2-stage compressors, and in other cases by the adoption of two compressors for each engine to supply the necessary air. The greatest care is essential in the design of valves. The minimum amount of lubrication must be supplied, and the cooling of the air during and after compression must be all-efficient. These difficulties have led some designers to develop and apply to 4-cycle engines a system whereby the fuel is delivered to the main cylinder in a sufficiently finely divided state, without the aid of compressed air, and this system goes by the somewhat erroneous name of "solid fuel injection."

The figures in Appendix I. show that no gain in economy with 2-cycle engines is to be anticipated, and, added to this, the following may be stated: (1) Owing to the more rapid combustion required with the 2-stroke cycle engine during its very much shorter working stroke, as compared with the 4-cycle, *i.e.*, combustion must be complete before the exhaust ports open, whereas with the 4-stroke cycle engine, the combustion may go on even slightly after the bottom dead centre without causing a bad exhaust—this system is more applicable to 4-cycle engines than to 2-cycle engines. (2) The injection of the fuel must be timed to take place much more accurately at the desired point than is necessary with compressed air for fuel injection. (3) Regulation for slow running is difficult to effect without elaborate timing and variable lift devices on the fuel injection valve. (4) The complications of the compressor are only eliminated at the expense of a considerable complication to the fuel-injection pump with its valves, &c., and the high pressure at which the fuel must be delivered, some 2,000lbs. per square inch, gives rise to further difficulties. (5) In changing from one fuel to another, troubles may be encountered in adjusting the delicate injection devices to accommodate the different properties of the new fuel. (6) The starting medium so far adopted for Diesel oil engines, other than some types for submarines, is compressed air, and for this a compressor, at anyrate, is necessary. (7) Initial warming to a considerable extent is necessary with the densest fuels, at the present time easily utilisable with compressed air injection.

For large cylinders, undoubtedly the possibility of "sticking," damage or breakdown of the fuel injection valve which is supplying the fuel for the combustion stroke of enormous power, cannot be contemplated, and multiple valves should be adopted. (See Fig. 1.) Safety valves, generally fitted to combustion spaces, do much to relieve the dangers of excessive pressures, but more than this is required. Table VI. gives compressor capacities in cubic feet per brake horsepower per hour, for a number of engines, and shows how the sizes of this unit varies with the type of engine, method of fuel injection, and margin desired for charging the starting reservoirs.

Valve Gears.—The design of valve gears does not present any grave difficulty, and although to the uninitiated the appearance is that of great complication, yet these parts are neither subject to pressure nor temperature, and each has a very definite function. The designer first determines the conditions to be satisfied by the valve gear, and the diagrams (Figs. 45 and 46) show those demanded in the past, whereas that of the future will probably follow the lines indicated in Fig. 47, where not only does the starting air gradually cut out and the fuel gradually cut in one cylinder at a time, but, in conjunction with the augmentation of the lift of the fuel-injection valve, the fuel-injection pump is proportionately put into action. The disadvantage of this method is, of course, when it is desired to cut out two and three cylinders for the purpose of running at reduced speeds. This cannot be done with the valve gear, but requires a separate

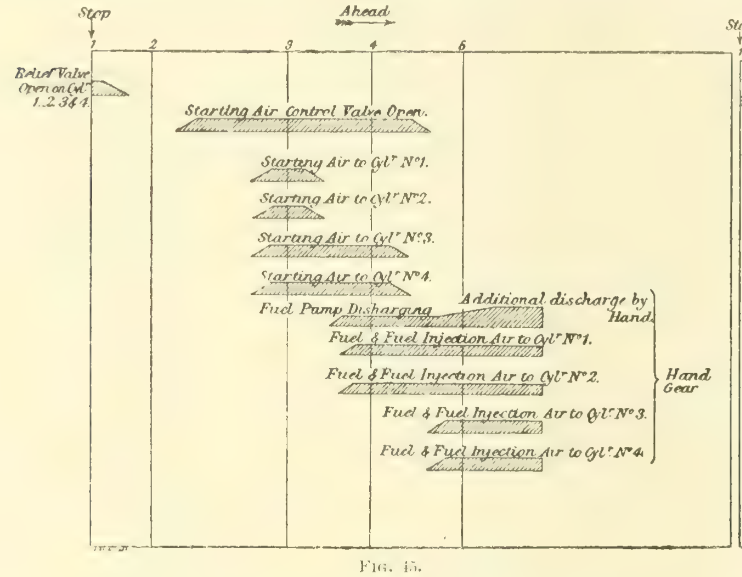


FIG. 45.

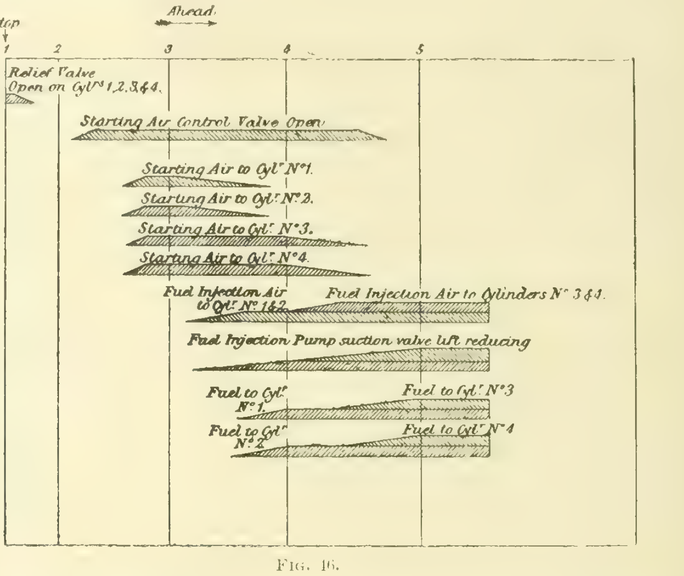


FIG. 46.

gear. To cut out individual cylinders, to cut out groups of cylinders, and to vary the lifts of individual fuel injection valves and the fuel-injection valves for groups of cylinders—to satisfy all these conditions undoubtedly calls for the greatest ingenuity, but is not by any means an insuperable difficulty.

Starting.—The means universally adopted of starting marine Diesel oil engines of large power is compressed air, primarily because this medium is the most convenient. So far, except with solid fuel-injection engines, a compressor is a necessary part of the main engine (although, of course, it can be separately driven) to supply the compressed air necessary for the injection of the fuel into the working cylinder in that finely divided state required for suitably quick ignition and combustion. By assigning to this compressor a capacity slightly greater than that required for the full-power injection of the main engine (see Table VI.), a margin is always available for recharging the storage of air to be used for subsequent starts. In considering merely the storage of that air, the questions of capacity and pressure must be decided. The limits of pressure are between the lowest pressure at which the engine will start with a sufficient degree of certainty, and the pressure at which the safety valve on the high-pressure side of the compressor is set (as determined by the injection pressure). In practice, these are, roughly, between 300lbs. and 1,000lbs. per square inch. The great majority of systems of starting 2-cycle engines work with the air at the higher pressure, as this necessitates considerably lower storage capa

* Paper read before the Junior Institution of Engineers, April 20th, 1914.

city and less complication to the engine valve gear by way of relieving compression. Throttling the suction in the main engine is applied to 4-cycle engines.

It may be stated that, with the exception of starting by means of low-pressure air in the scavenging pumps, the low-pressure system is applied only to 4-stroke cycle engines. The disadvantages of compressed air as a starting medium are considerable, in view of the high pressure and the consequent difficulties of safe storage. Suitable subdivision and duplication give immunity from complete loss due to any misadventure, but the cost is somewhat excessive. To this end it is desirable, whilst remembering all the aforementioned conditions of safety, to reduce the starting-air storage to a suitable minimum.

The curve shown in Fig. 48 shows the starting-air storage for a number of cases, chiefly, as will be seen, for 2-stroke for low-pressure systems. Per unit weight of air, the low-pressure system gives a greater number of starts.

The advantage of the low-pressure system is the simplicity of the reservoirs, which may be made of ordinary boiler form and construction, making thus for cheapness and increased safety. Either a separate compressor must be provided for this low-pressure air, or arrangements made to take it from the main compressor, which, without adopting some system of regulation entailing complication, means that the number of compressions as subdivided between the various stages is upset.

In future, the starting-air storage, whether high or low pressure, will undoubtedly be reduced when: (1) The confidence of experience is established; (2) the regulation of the fuel is so made that the chances of an engine failing to pick up on fuel immediately, due to any derangement of the

TABLE VI.—*Marine Engine Compressors.*

Ref. No.	Main Engines.							Compressors.										Remarks. (Unless otherwise stated the compressors are driven from the end of the engine crank shaft.)
									H.P. Stage.		I.P. Stage.		L.P. Stage.				
	Type of Engine.	B.H.P.	No. of Cylinders.	Revs.	Dia. of Cylinder.	Stroke.	[illegible]	No. per Engine.	Dia. in inches and m/m.	Stroke in inches and m/m.	Dia. in inches and m/m.	Stroke in inches and m/m.	Dia. in inches and m/m.	Stroke in inches and m/m.	[illegible]	Ft.³ per B.H.P. hour.	
	4-CYCLE.																
1	Crosshead ..	600	4	150	535 m/m 21″	770 m/m 30·3	6·06	1	3·5	11	9 3·5	11″	18·9	11	182	18·2	Driven by links from engine crosshead.
2	Trunk piston	600	4	310	450 m/m 17·7	510 m/m 20·07	2·86		90 m/m 3·54	11·4			290 90 m/m 11·4 3·54	11·4	188	18·8	Links from engine connecting rod.
4	,, (submarine)	350	6	500	11·4	11·8	·33	4 stage 1	1·94	8·6	1st I.P. 5·4 2·8 2nd I.P. 2·8	6·45	9·4 1·94	8·6	165	28·2	2 stages from crankshaft. 2 stages from levers from connecting rod of compressor
5	Trunk piston	200	6	330	240 m/m 9·449	360 m/m 14·17	·575	2	55 m/m 2·16	7·09	—	—	180 55 m/m 7·09 2·16	7·09	48·5	29·1	Reavell compressor.
6	,,	100	4	530	7·87	9·05	·254	1	2·2	4·64	-	-	7·75 2·2	4·64	62	37·2	
7	,,	300	3	175	440 17·32	640 25·19	3·48	2	65 m/m 2·55	270 m/m 10·63			220 65 m/m 8·66 2·55	270 m/m 10·63	58	34·8	
	2-CYCLE.																
22	Crosshead	1600	6	130	20	36·2	6·55	1	7″	10″	14″	10″	19·5	10″	438	16·4	Reavell quadruplex.
23	,, ...	1250	6	150	20	30	5·45	- -	-	—	- -	-	-	.	550	26·4	,, ,,
24	,, ...	1000	4	140	550 m/m 21·65	31·5	6·7	2	90 3·54	300 m/m 11·8	430 380 16·9 14·96	300 m/m 11·8	430 90 16·9 3·54	300 m/m 11·8	408	24·48	,, ,,
25	Trunk piston	1000	4	150	550 m/m 21·65	800 m/m 31·5	6·7	1	160 m/m 6·299	500 m/m 19·68	-		470 m/m 18·5 6·299	500 m/m 19·68	406	24·4	,, ,,
26	Stepped piston	900	6	260	14″	23	2·06	2	4·5	17	—		11·5 4·5	17	225	30·0	
27	Trunk piston	900	4	234	450 m/m 17·7	560 m/m 22	3·13	1	80 m/m 3·15	360 m/m 14·17	410 372 m/m 16·1 14·65	360 m/m 14·7	410–80 m/m 16·1 3·15	360 m/m 14·17	376	25	,, ,,
29	Crosshead ..	850	4	140	470 m/m 18·5	680 m/m 26·77	4·15	1	100 m/m 3·93	400 m/m 15·74	260 100 m/m 10·23 3·93	14·7	420 69 m/m 16·53 2·7	600 m/m 23·62	405	28·6	Balanced lever arrangement.
31	,, ..	750	4	150	500 m/m 19·68	700 m/m 27·56	4·85	-	—	-	-	-	.	-	320	25·6	
32	Double piston	650	3	180	390 m/m 15·35	450 m/m 17·7	3·76	1	4·75	19	—	- -	16·5 4·75	19	388	36·0	
33	Crosshead ..	500	4	170	400 m/m 15·75	650 m/m 25·6	2·88	2	3	11·5	-	—	22·5 3	11·5	130	31·2	Driven by links.
34	,, .	500	4	150	430 m/m 16·9	610 m/m 24·02	2·8	2	70 m/m 2·76	225 8·86	340 300 m/m 13·39 11·8	225 8·86	340 70 m/m 13·39 2·76	225 m/m 88·6	206	24·8	
35	Trunk piston	500	6	310	12·25	15·375	1·05	1	4·4	12·6	—		13·2 4·4	12·6	275	33·0	. .
36	,,	440	4	215	13·78	19·7	1·7	2	2·34	15·8	-		7·2 1·98	15·8	148	20·2	
37	,,	380	4	250	310 m/m 12·2	460 m/m 18·11	1·22	1	2·75	9·85	7·08 2·75	9·85	11·8	13·77	218	34·0	Balance lever arrangement.
38	Stepped piston	325	6	500	250 m/m 9·8	270 m/m 10·6	·46	1	75 m/m 2·95	180 m/m 7·09			250 75 m/m 9·8 2·95	180 m/m 7·09	140	25·8	,, ,,
40	Trunk piston	260	4	250	290 m/m 11·4	430 m/m 16·93	1·0	1	65 2·56	330 13	—	-	215 8·46	330 m/m 13	96	22·2	Scavenging pumps and compressor grouped.
42	Stepped piston	150	6	500	7	9	2·40	1	2·4	9″		.	7·5 2·4	9″	103	41·2	

cycle engines, as indicated by the full dots, as against the others for 4-stroke cycle engines. Against all the points is indicated whether they are for a high-pressure or a low-pressure system, and, in the case of low-pressure systems, the pressure of the system. Further, the number of starts specified or attained is also added above many of the points.

It might be contended that the starting-air storage should not be equated against a brake horse-power basis, but rather against a main engine cylinder-volume basis; but the author's experience is that the normal speed of revolution of the engine is a factor of importance, and must be included by equating storage against brake horse-power. Further justification for the method adopted is found in the manner in which, generally, the points seem to follow a definite line, and the starting-air storage works out at from 0·1 to 0·2 cub. ft. per brake horse-power for 20 to 30 starts specified for high-pressure starting, and about 0·25 to 0·35 cub. ft.

fuel-injection pump valves or to any air in the fuel-pump passages or pipes, is minimised; (3) if some system of preliminary warming up of the engine be adopted.

This last clause is by far the most important of the three, as, due to the slow compression at a low number of revolutions, a considerably greater amount of heat passes from the cylinder walls from the air being compressed in the main cylinder than will normally be the case, so that from this cause the compression temperature does not reach the normal. Further, the expansion of the starting air into the working cylinder from approximately the starting air pressure throttled to the exhaust pressure or that of the atmosphere, cools down the whole cylinder, and so further aggravates this starting difficulty.

The heating up of the starting air prior to its introduction into the cylinders is not exactly practicable, but the ensurance that the cylinders are hot before starting requires but a short

time, is beneficial in preventing them from being subjected to unreasonable heat treatment, is easy of attainment, costs little, and would go far to reduce the starting-air storage to a minimum.

The tendency in the future will, undoubtedly, be to adopt low pressure starting air systems for 2-cycle engines on

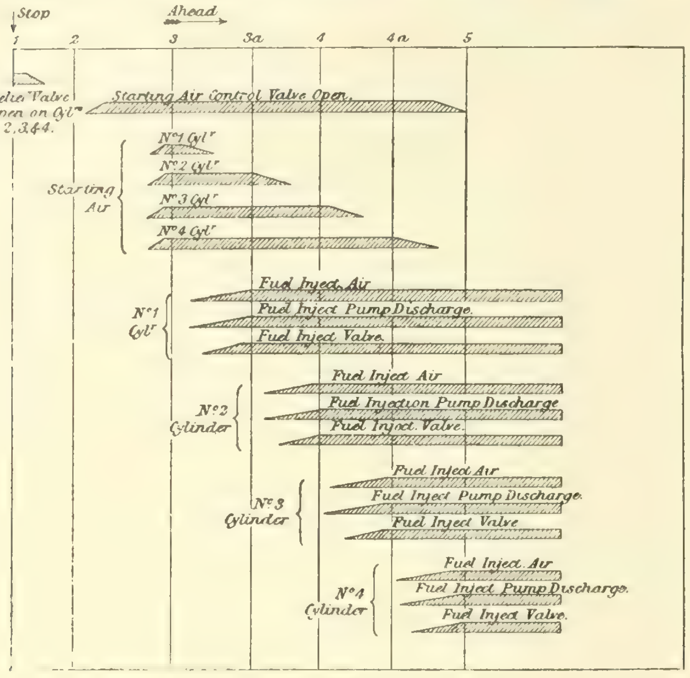


FIG. 47

account of the aforementioned advantages. These systems will not be applied, as hitherto with such engines, by using the scavenging air pumps as the starting cylinders. This necessitates a greater strength of these parts, especially with large engines, than would otherwise be required, and entails also the pumps being connected to the main engines in a suitable manner for transmitting the starting torque. A probable method will be by relieving the compression pressure in the main cylinder and so permitting of the required starting effort being given by air of considerably lower pressure than is at present adopted.

Weight.—The question of the weight of large engines is exemplified in Table VII., which gives the weight of various installations with and without the auxiliary machinery. As this question is bound up, primarily, with those of speed of revolution and power per unit volume of cylinder, the weights have been plotted (Fig. 49) on a brake horse-power basis, as constructed, and also, in Fig. 50, on the same basis corrected for a constant mean effective pressure and speed of revolution. These curves show the influence of the type of framing upon the weight. For curve A for engines of the mercantile steam engine framing, the weight works out at 280lbs. per brake horse-power. Curve B, for the through bolts and cast column type of framing, 224lbs. per brake horse-power. Curve C, through bolts only, 180lbs. per brake horse-power—all for a mean effective pressure upon a brake horse-power basis of 60lbs. and a speed of revolution of 150 revs. per minute.

Means will be adopted in the future to increase the mean effective pressure when suitable material is found to withstand the increased temperatures, and, with greater experience, not only will a higher speed of revolution and a higher piston speed be probable, but confidence will result in a reduction of the scantlings and the weight per unit power from those given by these curves, although, in general, the larger the power the greater the weight per unit power. The circles indicate 4-cycle engines and show that the gain in weight for the 2-cycle engines up to the present is small.

Interchangeability and Machining Operations. Many schemes for the application of Diesel engines as at present developed have been suggested for the propulsion of ships of the highest power, and indicate that there will be a multiplicity of units each exactly like the other. It is not proposed to deal with or compare the relative feasibility of any of these applications.

No great loss in efficiency, no great increase in weight, space occupied, or cost, is to be anticipated as a result of this multiplicity, but its effect upon the methods of dealing with the problem of the construction of higher power installations is instructive. Not only then to give interchangeability with this multiplicity of units, but on account of the great pressures and their high rates of application, is the necessity for extreme accuracy in the machining and fitting of the various parts obvious. To this end, machining must be carried out absolutely to gauge, making use of the most modern machine tools and tool-room and control methods. The multiplicity of parts adds further to the necessity for using jigs and fixtures for almost all operations, and tends towards the application of bonus, piecework systems, card systems, subdivision of work, and sectioning.

TABLE VII.—*Weights of Diesel Engines.* (*See Figs. 49 and 50.*)

Reference No.	Cycle.	No. of Cylinders.	B.H.P.	Revs./min.	Diameter.	Stroke.	Type of Engine Structure.	Weight of Engines. lbs.	Tons.	lbs. B.H.P.	B.H.P./ton.	Remarks.
3	2	4	750	150	19·68	27·55	—	182·200	81·5	244	9·2	
4	2	4	500	150	16·92	24	—	90·000	40	180	12·5	Equipment = 3 to 4 tons extra.
5	2	4	1000	140	21·65	31·5	Crankcase and through bolts.	220·000	98·5	220	10·3	,, = 7·55 tons extra.
9	4	6	500	400	13·78	13·78	—	33·000	14·72	66	34	
10	4	4	750	120	18⅜	32¼	C.I. columns.	224·000 336·000	100 118* 150†	300 447	7·5 5·0	*With shafting and propeller. †With auxiliaries.
11	4	6	2000	—	—	—	,,	671·000 1120·000	300 500†	335 560	5·95 3·58	†With auxiliaries.
12	4	6	1500	115	20	36·2	,,	403·000 785·000	180 350‡	268 524	8·35 4·29	‡With auxiliaries and shafting and propeller.
13	4	4	850	140	18·5	26·77	C.I. Y columns and through bolts.	143·000 196·000	64* 87·5†	168·5 230	13·3 9·7	*Engine + 8 ton flywheel. Auxiliaries with 9½-ton flywheel.
14	4	8	1250	140	20·86	28·75	C.I. crankcase and through bolts.	318·000	142·5	254	8·80	Auxiliaries 88 tons for two engines.
15	2	4	440	215	13·78	19·7	Crankcase and cylinder jacket integral.	94·000	42†	214	10·5	†With auxiliaries.
16	2	4	1600	110	27	38	—	461·000	2·06	288	7·76	
17	2	6	500	310	12¼	15¾	Crankcase and through bolts.	33·000	14·72	66	34	
18	4	4	100	530	7·87	9·05	Crankcase.	6·200	2·15	62	46·5	§Includes water and oil: Water 2 cwts., Oil 44lbs.
28	2	6	1150	130	17·3	31·4	C.I. columns.	280·000	125	244	9·2	Separately driven compressor. Auxiliaries 163 tons. Propeller and shafting 157 tons (for two engines).
29	4	8	1200	125	19·68	31·5	Crankcase and through bolts.	482·000	215	355	5·6	Auxiliaries 150 tons (for two engines).
30	4	4	200	250	15¾	20	Turned steel braced structure.	58·200	26	290	7·7	Auxiliaries 32·5 tons.
31	4	6	1100	115	22·09	39·4	,, ,,	262·000	117	263	9·4	Auxiliaries = 146 tons.
32	4	6	1100	115	22·09	39·4	,, ,,	262·000	117	263		Auxiliaries = 162·5 tons.

Under the heading dealing with cylinders and other main parts, the necessity for the highest class of materials to resist the combined temperature and pressure effects has been discussed, whilst the power pressure question requires, as already dealt with under "*Pressure Parts*," the careful selection of that material most suited for the particular work required of it. In spite of this, with such plant designed and laid down, such organisation inaugurated and systematised, the work should be carried out relatively at a figure con-

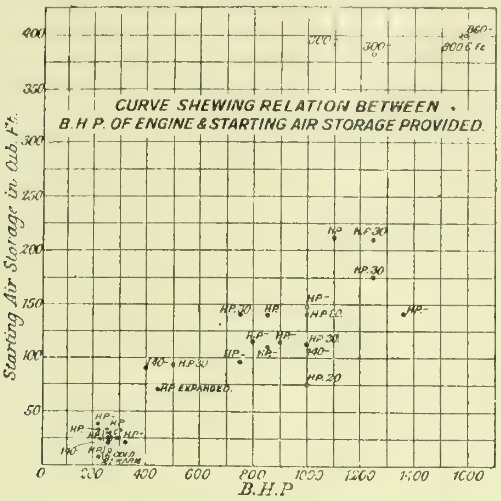


FIG. 18.

siderably lower than one based on the methods so far applied in this country to the construction of marine Diesel engines. If economic or naval considerations be such that the engineer is called upon to develop the oil engine for high powers, and naval authorities seem agreed as to the necessity for this, it has been attempted, without defining what constitutes

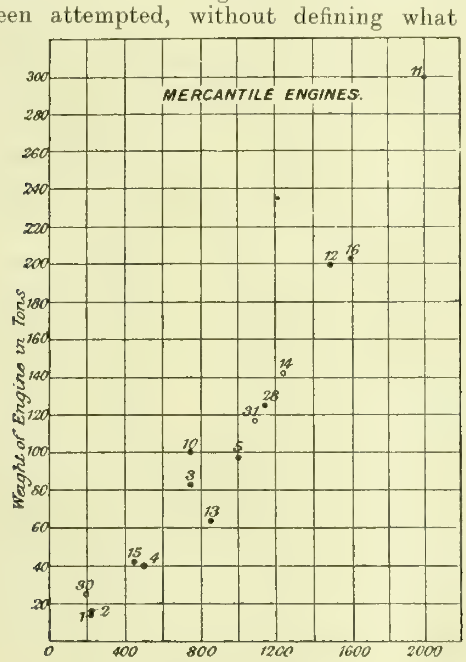


FIG. 19.

"high power," to indicate in this paper the lines along which that development should proceed.

APPENDIX I.

The case for solid-fuel injection is worked out as under, for a 2-cycle engine of dimensions:—

Four cylinders—450 b.h.p. at 200 revs. per minute.

Diameter cylinders—14·75in. stroke = 22·5in. with a mean effective pressure of 58lbs. per square inch on a brake horse-power basis.

The amount of air available for combustion per hour is:—

Charging air = 6,480lbs. per hour = 92·7 per cent.
Fuel injection air = 512lbs. per hour = 7·3 per cent.
Total = 6,992lbs. per hour.

NOTE.—The charging air is based upon an efficiency of scavenging of 80 per cent., and the fuel injection air, when a consumption of 112 cub. ft. per minute or 25 cub. ft. per brake horse-power per hour, allowing for the inefficiency of the suction and the throttling of the compressor.

I.H.P. = Total of all brake horse-power

∴ I.H.P. = Fuel + Air + Friction of main engine (not including compressor or scavenging pumps) + Scavenging + Compressor

$$= 64\% + 4\% + 14\% + 10\% + 8\%$$

For air injection engine = 424 + 26 + 92·8 + 66 + 53 = (say) 662.

For solid-fuel injection engine (1) = 394[1] + 0 + 80[2] + 66 + 0 = 540.

For solid-fuel injection engine (2) = 450 + 0 + 92 + 76[3] + 0 = 618.

(1) This figure is obtained by assuming that the brake horse-power obtainable from the fuel is in the ratio of the amount of air available, *i.e.*, 424 × 0·93 = 394.

(2) The brake horse-power lost in friction has been reduced to the ratio of the reduction of the power of main engine, *i.e.*, $93 \times \frac{394}{450} = 80$.

(3) The power absorbed by the scavenging pumps is increased in the ratio of the increase of size of cylinder, *i.e.*, $66 \times \frac{450}{394} = 76$.

NOTE.—The solid-fuel injection engine (1) is an engine of the same *cylinder volume* as the air-injection engine, and solid-fuel injection engine (2) is an engine of the same brake horse-power as the air-injection engine.

Assuming that the fuel consumption per indicated horse-power is constant, and = 0·34lb. per indicated horse-power hour,

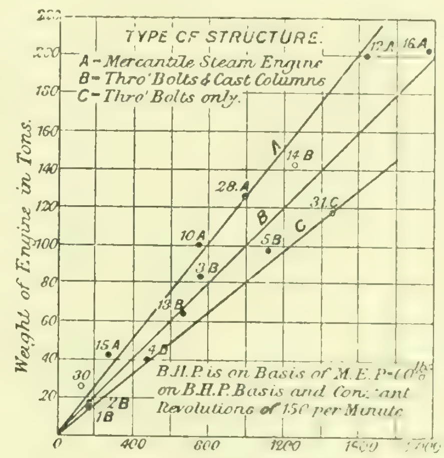


FIG. 20.

Then for the air-injection engine $0·34 \times \frac{662}{450} = 0·5$lb. per brake horse-power hour, and for the solid-injection engine (1) $0·34 \times \frac{540}{394} = 0·47$lb. per brake horse-power hour.

Solid Fuel Injection. Table of Comparison.

Particulars.		Fuel injection with compressed air.	Solid fuel injection (1).
Combustion air	lbs. per hour	6480	6480
Compressed air for fuel injection	..	512	0
Total air available for combustion	..	6992	6480
Indicated horse-power:—			
Fuel	B.H.P.	424	394
Fuel injection air	..	26	0
Friction loss	..	92·8	80
Scavenging loss	..	66	66
Compressor loss	..	53	0
Total	..	662	540
Fuel consumption, lbs. per B.H.P. hour = 0·34lbs. per I.H.P. hour × Total I.H.P. / B.H.P. fuel + air		0·50	0·47
Fuel consumption with ·93 efficiency of spray of solid fuel injection			0·505

Engines above have same cylinder dimensions, and are assumed to run at the same speed of revolution.

If 0·93 be the efficiency of the solid-injection spray, then the consumption $= \frac{0·47}{0·93} = 0·505$lb. per brake horse-power hour.

The fuel consumption for solid-injection engine (2) $= 0·34 \times \frac{618}{450} = 0·47$,

and the efficiency of spray of solid fuel injection system = 0·93 and the consumption = 0·505lb. per brake horse-power hour.

FLAME CARBON ARC LAMPS.

At the meeting of the Pittsburg Section of the Illuminating Engineering Society on April 17th, Mr. C. E. Stephens presented a paper on "The Development of Flame Carbon Arc Lamps." Flame arc lamps could, he said, be classified as open-flame carbon arcs and enclosed-flame carbon arcs. In the former the arc was maintained between mineralised carbons, inclined together at an angle of approximately 25°, with the arc chamber thoroughly ventilated. Because of the free oxidation the carbons were consumed quite rapidly, the life being 16 to 20 hours, depending on their length. The method of forming the arc between inclined carbons necessitated the use of carbons of small diameter to ensure that the ends would burn evenly; hence, to secure a reasonable life, carbons of comparatively great length were required. The long, small-diameter carbon was necessarily expensive.

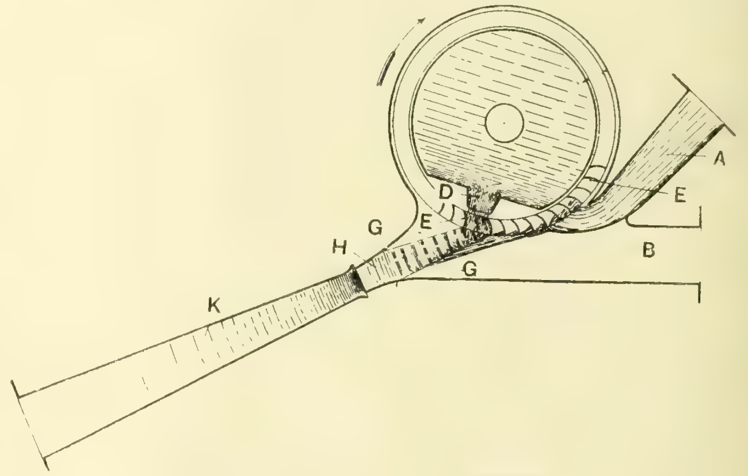
The open-flame carbon arc lamp was, he considered, useful only where large quantities of light were required, outdoors, and in some industrial establishments where the areas to be lighted were great and mounting heights high. The light efficiency was high, but the distribution was such that the maximum intensity was directly under the lamp, and this made the lamp unsuitable for producing a uniform illumination over large areas. The mechanism was complicated, and the lamp required frequent attention. In order to secure a long-burning open-flame carbon arc lamp, various magazine types had been devised. In general, these lamps had been commercially unsuccessful, because the quantity of carbon consumed was approximately the same, the only saving being in the labour of trimming. Also the magazine added to the complexity of the mechanism. Early attempts to lengthen the carbon life by restricting the air supply resulted in a heavy deposit of white powder over the glassware, which in a short time became so thick as to absorb practically all the light. The problem was so to dispose of the metallic fumes that the glassware would remain comparatively clean throughout an entire trim of carbons, which should be 100 to 125 hours. This was achieved in the modern lamps.

The enclosed-flame arc was maintained between mineralised carbons in an enclosure where the air supply was restricted. The carbon formed the conducting vapours, and the illuminosity of the arc depended on the quantity of the mineral salts vaporised. The vaporisation must be uniform to produce a steady light. Practically all of the light emitted came from the arc flame, and only a very small portion from the incandescent craters on the carbon ends. The carbons were vertical and superimposed, so that the arc flame was also vertical. The diameter of the carbons was approximately ⅞in. and their length 14in. The rate of consumption was comparatively small, allowing a simple and rugged mechanism, which was a modification of the ordinary enclosed carbon arc mechanism, the difference being in the sneak feed and the focussing arc principle. In other words, the carbons were fed into the arc simultaneously, at rates depending upon their relative consumptions, maintaining the arc in a fixed position, and they were fed gradually instead of by steps. The fumes from the arc were deposited in a relatively cool condensing chamber above the globe.

The successful operation of the lamp was, he observed, entirely dependent on the character of the carbons. The cored type had not proved successful, and modern carbons were homogeneous, showed an efficiency of 0·2 to 0·3 watt per mean lower hemispherical candle-power and a life of 100 to 125 hours. The maximum candle-power was from 10° to 30° below the horizontal, making the lamp particularly adapted to the illumination of large areas. A particular advantage of the flame carbon lamp was that it was suitable for either direct or alternating-current circuits and for frequencies as low as 25 cycles. The efficiency of the enclosed-flame arc lamp was much better than that of the new nitrogen-filled tungsten lamps; moreover, it was susceptible of improvement, while the latter was near the theoretical limit of its efficiency. The efficiencies of the new tungsten lamps were given for clear glass globes, and when they were enclosed in suitable diffusing glassware the efficiency would be still lower. The tungsten lamp was undoubtedly desirable for series circuits in residential sections, and the gas-filled lamp would probably enlarge this field somewhat; but the author was of opinion that it would never compare favourably with the flame arc lamp for business streets, boulevards, parks, driveways, city squares, and other areas where there was any great amount of traffic and which required a high illumination intensity. The new high-efficiency Mazda lamp was too new to predict its limiting field with any degree of accuracy. Its immediate effect would probably be to entirely wipe out all of the old enclosed carbon arcs, to extend the present field of the tungsten lamp, and to accelerate improvements in flame arc lamps of both the flame carbon and metallic flame types.

ROTARY AIR PUMP FOR SURFACE CONDENSERS.

The accompanying illustration shows an arrangement of wet vacuum pump for extracting from a surface condenser not only the air and the non-condensible gases but also the water of condensation, the invention of Messrs. Westinghouse-Leblanc, 7, rue de Berlin, Paris. The rotary pump is constituted by a turbine wheel, as shown, furnished with a crown



ROTARY AIR PUMP FOR SURFACE CONDENSERS.

of blades E and driven in the direction of the arrow by any suitable motor. The fixed nozzle D directs water upon the crown of blades which sprays it into the chamber G which is in communication with the pipe H and the diffuser K. At another part of the periphery of the movable wheel a suction conduit A is provided, opening at a suitable distance from the orifice of the nozzle. The water to be withdrawn from the condenser is supplied to this conduit. The moving blades communicate kinetic energy to the water of condensation and propel it in the direction of the spray of water issuing from the air pump in such a manner that the water from the condenser, the water from the air pump, and the air withdrawn by the pipe B are simultaneously forced into the diffuser K. Experiment shows that the speed of the water spray from the air pump is not appreciably diminished by this action and that consequently the pneumatic power of the air pump is not altered.

Fatal Explosion on a German Steamer.—An explosion occurred in the bunkers of the German steamer "Deike Richmero," bound from Swansea to Hull, when nearing the Isle of Wight, two firemen being so seriously burnt that they subsequently died.

PRECISION DISTANCE TACHOMETER SET FOR WIDE RANGES OF SPEED.

The speed-testing set illustrated herewith has been specially designed for extremely accurate measurements of the speed of engines during efficiency tests extending over a range of speed from 100 to 4,800 revs. per minute. It is particularly suitable for use in testing stations of automobile works, physical laboratories, &c.

The set, which is manufactured by Messrs. Schaffer and Budenberg, Ltd., Whitworth Street, Manchester, consists of a small magneto-multi-generator (transmitter), Figs. 1 and 2, and two measuring instruments (receivers), one of which is a dial-tachometer for general determination of the speed, and the other a resonance type tachometer for very exact measurements.

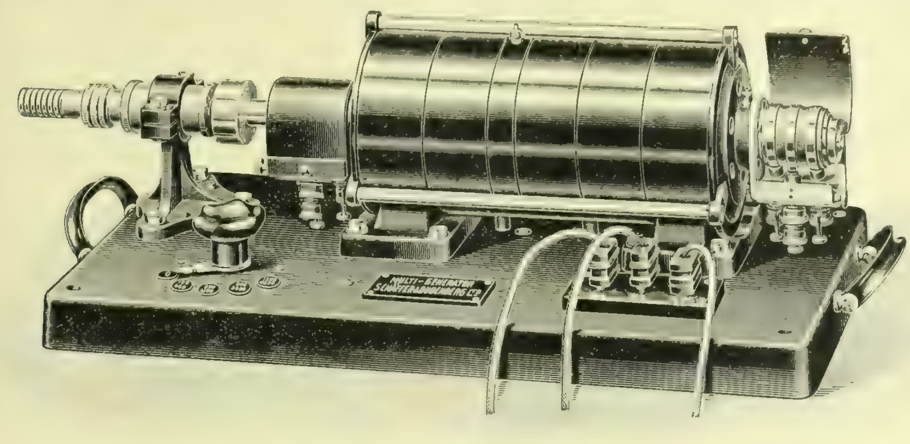


Fig. 1.—Multi-Generator. Precision Tachometer.

The small dial-tachometer shown in Fig. 3 is essentially a voltmeter of the electro-magnetic type, with the scale divided directly in revolutions per minute. In this type of instrument, which has for some years been used for measuring electricity, a solenoid, excited through the current produced by the generator, magnetises equally two soft iron segments so that they repel each other with a force depending on the speed of the generator. One of the segments is fixed whilst the other is mounted so that it can revolve freely in sapphire bearings, and, being fitted with a pointer, forms a sensitive and very reliable indicator. The well-damped, revolving system of the instrument weighs only ·9 grammes (·0315oz.).

The resonance-type tachometer, shown in Fig. 4, is a precision-measuring instrument which is unquestionably absolute as regards exactness of indications and reliability. It consists essentially of an electromagnet, the windings of which are excited by the alternating current of the generator and a series of steel and resonance reeds arranged in one or two rows within the field of the electromagnet. These steel reeds are mounted on a frame, the free end of each reed being bent over at right angles for about ⅛in. The head thus formed is coated with white enamel so as to render it easily visible. In the angle formed by the head with the stem of the reed a small drop of solder is placed to weight the reed. The reeds vary in length, &c., to suit the scale required, and are carefully tuned so that their rate of vibration synchronises with the magnetic alternations of the exciting circuit.

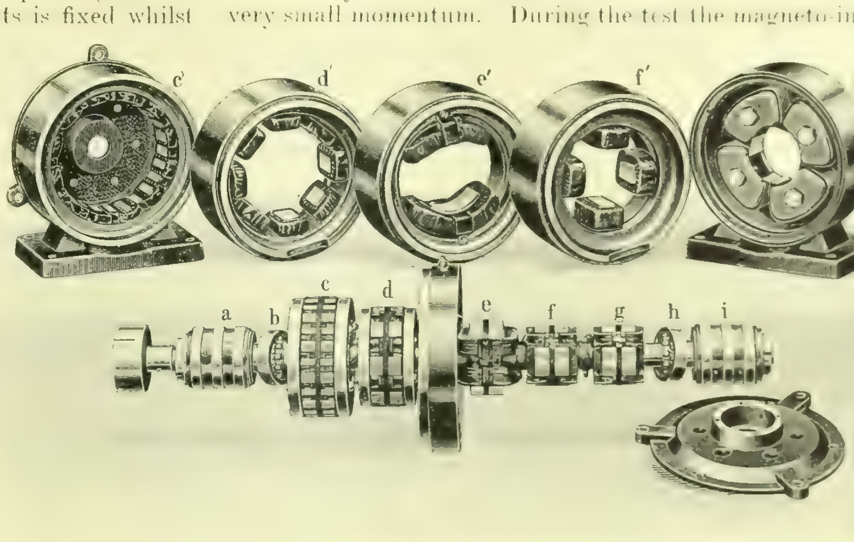


Fig. 2. Multi-Generator Dismantled.

The essential advantages of the resonance system are the absolute precision of indication which nothing can influence and the absolute indifference of the apparatus against even the roughest treatment. The indications of the apparatus will not vary in the least with the lapse of time. Apparatus of this class have been in continuous use for a large number of years, and although some of the reeds must have made thousands of millions of vibrations no detrimental change has taken place, and the reeds still possess their original natural period of vibration. The degree of accuracy of the indications is not affected by the variation in the resistance of the conducting cables, nor the voltage of the magneto generator. The indication, in fact, depends solely on the frequency of the impulses or the number of revolutions of the generator.

Simple resonance systems actuated by a single generator with only one definite number of alternations for each revolution are suitable only for a range of scale extending to twice or four times the initial speed as the maximum, as, for instance, from 100-400 revs., 200-800 revs., or 400-800 revs., &c. If, however, a multi generator is employed, which for each revolution produces a number of different alternating values, it is quite easy to multiply the first range of measurement by successively switching on the generator systems with a lesser number of alternations as the speed increases. The multi generator in the present construction consists of four small alternating-current generators, with 24, 8, 4, and 2 alternations per revolution, respectively, for actuating the resonance tachometer (precision indicator), and also of a small magneto inductor for actuating the dial and finger indicator. Referring to Fig. 2, c, d, e, and f are the armature windings of the alternating-current generators, g the armature winding of the magneto inductor; c', d', e', and f' are the cases containing 24, 8, 2, and 4 pole electromagnets, respectively, whereas g' shows the case with permanent magnets of the magneto-inductor. All the armatures are arranged on a common shaft mounted in three precision ball bearings, which is driven by flexible shaft or by strap from engine shaft. The adjustment is of ultimate precision and the rotating masses remarkably small, so that the whole forms a common rotor of very small momentum. During the test the magneto-inductor continuously actuates the small dial indicator. Of the four alternating-current generators only one at a time is excited by turning the pointer of the lever switch on the base of the multi-generator to the plate which shows the speed range indicated by the small indicator, as explained later.

To use the testing set the magneto-inductor is first connected to the small dial indicator. The latter is merely intended for averaging the speed and to act as a guide for switching on one of the four alternating-current generators. To effect this expeditiously a thick line is provided underneath the scale of the dial indicator divided into four sections, each of a different colour, the colours corresponding with

those of the figures of the four scales of the large resonance tachometer, *i.e.*:

		No. of Poles of Induction.
Blue for speeds	100-400	24
Red ,, ,,	300-1,200	8
Black ,, ,,	600-2,400	4
Green ,, ,,	1,200-4,800	2

If now the pointer stands over the blue segment of the dial the 24-pole generator is excited with continuous current by switching the lever of the switch to the blue circle (marked

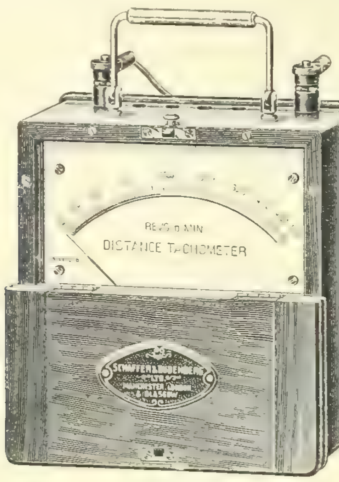


FIG. 3.—SMALL DIAL-TACHOMETER.

also 100-400), and the blue figures are read on the four scales of the large resonance indicator. If the speed increases beyond 400—*i.e.*, if the finger stands over the red mark—the switch is moved over to the red circle (300-1,200), thus exciting the 8-pole generator. The red figures on the four scales of the large indicator are then read. There are

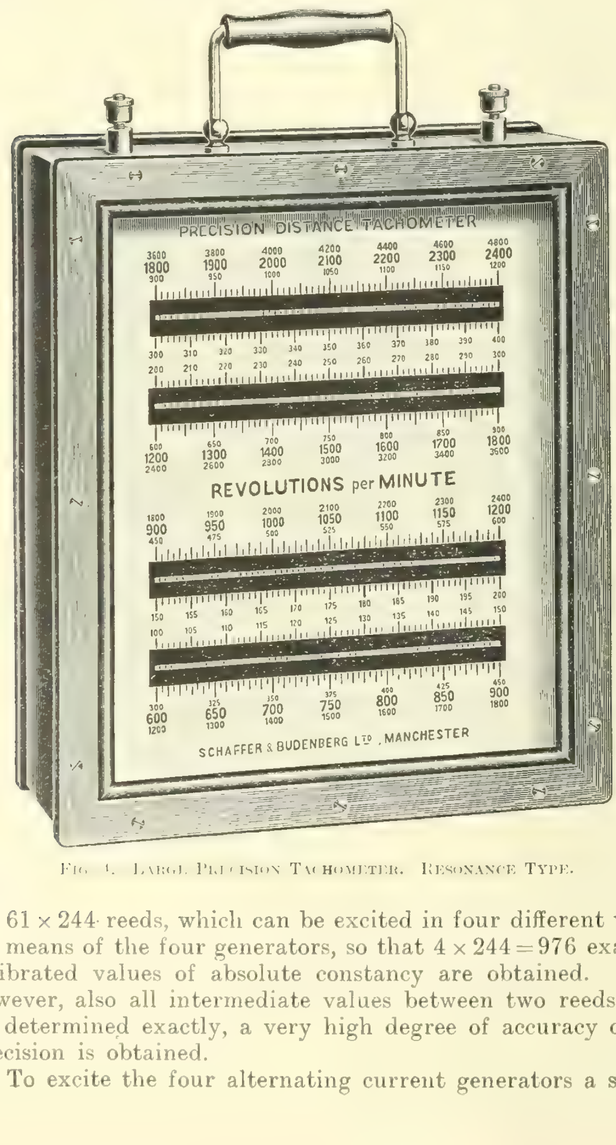


FIG. 4. LARGE PRECISION TACHOMETER. RESONANCE TYPE.

$4 \times 61 \times 244$ reeds, which can be excited in four different ways by means of the four generators, so that $4 \times 244 = 976$ exactly calibrated values of absolute constancy are obtained. As, however, also all intermediate values between two reeds can be determined exactly, a very high degree of accuracy or of precision is obtained.

To excite the four alternating current generators a small portable 12-volt accumulator may be used or current from a high-pressure main of 100 or 200 volts. The consumption of current at 12 volts is about 1 ampere for the 24-pole generator and a little less for the generators with lesser number of poles which are used for the higher speeds.

MACHINE-HOUR COST ACCOUNTING.*

BY CLINTON H. SCOVELL.

THERE is more reason now than at any time for many years why manufacturers should consider most carefully the problems of finance and management of their business undertakings. Facing the prospect of increased foreign competition in some lines, and the tendency towards higher wages which inevitably follows the increased cost of living, manufacturers necessarily are interested in any ways or means to make their industrial operations more efficient. Many things contribute to the efficiency of shop management. When a business is small, its success usually depends on the ability, foresight, and good judgment of one or two energetic men. As the business grows, methods and system must more and more take the place of the manager's personal oversight, and the need increases for accounting sound in principle and simple in operation.

Under the influence of the new science of management, there has been a constant study in the last few years of manufacturing methods, operating standards, cutting speeds, &c., resulting many times in such marked increases of production that the management may be sure that an improvement has been made, even if they do not know exactly *how much* saving has been effected. It has been clearly established, however, that the cheapening of manufacturing operations which is brought about by a better operating practice is frequently secured at a considerably increased cost for office force, planning departments, helpers, supervision, and other indirect labour, sometimes wrongly called non-productive. As a result the practical problem for the manufacturer is to compare the lessened direct cost for labour and equipment with the increased cost for the other factors. This he can do only when he has an adequate cost accounting practice.

It is my purpose to point out the essentials of a cost system for a machine shop, or a manufacturing plant where the operating conditions are similar, with especial reference to the theory and practice of a machine-hour rate. Good cost accounting depends on the correct application of a few well-understood principles. The first is to have the direct charges from the original sources, that is, pay-roll and material distributions, correctly classified between direct and indirect costs, and then to determine how the indirect, or so-called non-productive charges, may be identified with the product. Any cost accounting practice worthy of the name should record accurately the direct labour costs. In a machine shop, or under similar conditions, this direct labour cost should be applied with precision to each job going through the shop. *Very little cost accounting practice, however, has attained any similar precision for distributing the indirect charges for equipment, referred to hereafter in this article as burden.*

As the difficult and important part of cost accounting is to determine how a correct distribution of burden may be accomplished, it is clearly worth while to consider briefly the elements of burden. It is a tedious and expensive undertaking to build and equip a new plant, and to complete the cycle of manufacture from design to finished product; and there is much to gain in the way of a clear understanding of costs, if we trace out this development, step by step, taking careful note of the elements of the problems as we proceed.

When a new industry is to be established, the directors first buy a parcel of land suitable for the location of the proposed shop. Shop buildings are next erected. Unlike land, the buildings will require constant repairs; even then they are subject to a slow but certain deterioration and obsolescence that must be met by a charge for depreciation. To protect the investment, the owners must pay insurance and provide watchmen. To make the buildings usable, they must be heated and lighted, supplied with water and fresh air, and regularly cleaned. The striking thing about these charges

* Abstract of paper presented before the National Tool Builders' Association.

is that they all go on without any abatement, unless the shop is shut down, and even then the principal charges interest, taxes, insurance, repairs, and depreciation abate scarcely at all. All of this expense has been incurred by the management to provide suitable areas for the intended manufacturing process. If there are five or six sub divisions, each one may occupy an entire small building, or all or part of a floor in a larger building. Whatever the details, each uses so many hundred square feet of floor space and must carry its proportionate share of the land and building charges.

Within a department there may be one or more different operations, such as milling, grinding, boring, turning, planing, fitting, and assembling. The equipment in each case represents an investment of capital; it requires the payment of taxes and insurance; it suffers depreciation even more rapid than the building, and it incurs charges for power, repairs, and such indirect items as superintendence, inspection, and helpers' services. If the shop shuts down, the power may be shut off and the foremen dismissed; but so long as it runs, however short handed, or however inefficient, these charges do not change materially; and the fundamentals of interest, taxes, insurance, &c. (with the possible exception of repairs), are not one less.

All that has been described so far is overhead expense, more properly termed *burden*, and does not include any labour ten castings from a given pattern which has already been made, but the production of a machine tool involves orders for castings of many different patterns and sizes, bar stock for forgings, &c., and these material orders are all simple in comparison with the complex schedule of machine operations which are required to produce the finished part. All recognise how important it is that parts should be made in quantities that are economical and that the different pieces required should all be ready together on the assembly floor. It is, therefore, of the utmost importance to make effective plans to initiate and control the production so that these results may be accomplished. The management will then have a definite schedule of manufacturing operation on which costs may be determined by orders, by lots, by individual parts—with as much or as little detail as may be necessary.

Returning to the subject of specific costs, the first step is to provide such labour records, preferably with good automatic time stamps, as will make possible the necessary distinction between direct and indirect operations, and the exact time devoted to each lot of material or each expense order. The next step is to compute the burden correctly for each department, including interest, taxes, insurance, and depreciation on the buildings and equipment, and the additional charges for power, supervision, and repairs. In many industrial plants *manufacturing expense* includes only part of the e

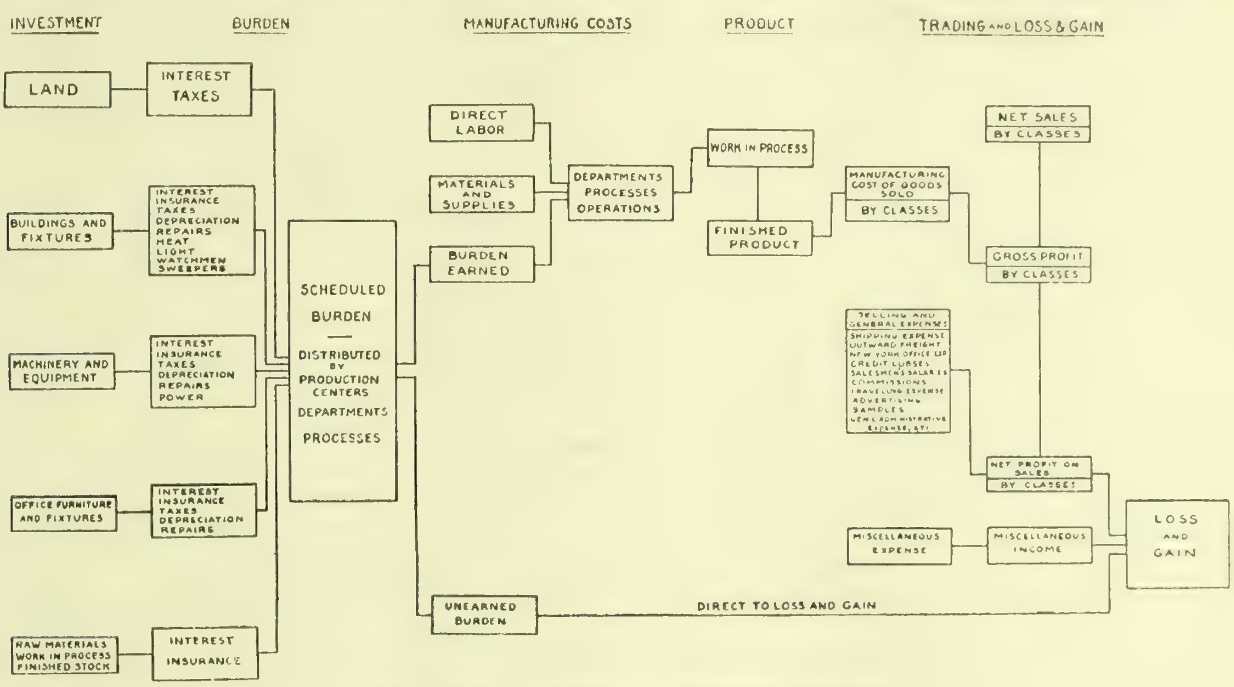


DIAGRAM OF TYPICAL ACCOUNTS FOR A MANUFACTURING BUSINESS.

applied directly to the product. This great accumulation of burden *represents manufacturing capacity*. Each department and each separate machine tool has a known annual burden. Its cost per hour is determined by dividing the total burden by the hours in the working schedule, and the shorter the schedule, the greater the hourly cost.

Having completed the buildings and installed the equipment, the management is ready to begin manufacturing operations. As the several parts of the machine progress from rough castings or forgings to finished pieces ready for the assembling floor, their value has increased as they have absorbed the successive increments of direct or productive labour, and of the burden pertaining to the production centres through which they have passed.

Before illustrating the practical application of this theory, I want to point out that good cost accounting is a help to efficient management, not only as it traces and records values, but also as it may be made a powerful agent for production control. From my experience in professional service for industrial plants, I emphasize more and more the practical value of this second aspect of the work. It follows, therefore, that the first step in planning a cost accounting practice for a machine shop is to consider by whom and how authority to manufacture shall be made. It is simple enough to order charges. The first cost of manufacturing is plant investment —land and buildings. No management using a rented plant would think of omitting rent from overhead charges. When the manufacturer becomes also a landlord, as when the plant is owned by the manufacturing company, what sound reason can possibly be given for omitting from burden the charges which the management incurs in lieu of rent?

The equipment presents a slightly different problem. Few manufacturers operate with rented equipment; if they do, there is rent to pay, as an unavoidable burden on the manufacturing operations. When the equipment is owned, the maintenance charges are equally unavoidable. The manufacturer must get interest on his investment before he has in any sense a profit, and he must bear the expense of taxes, insurance, depreciation, and repairs. Although these elements of cost may be neglected, or not stated, they are, nevertheless, taking their proper share, or more, of what is figured without them as gross profits.

The weakness of many cost systems is that important elements of indirect cost are thrown together in a *general expense* account, concealing the leaks and wastes that reduce efficiency and curtail profits. Many manufacturers have no doubt been satisfied to handle burden in vague and general terms because they did not know any better way to dispose of

it. It may be stated confidently that under ordinary machine shop conditions no accurate distribution of burden can be accomplished, and, therefore, no accurate costs determined, by spreading the burden over all the work done in the shop as a percentage of the cost of direct labour. In the shop proper, with its widely varying equipment of machine tools, distribution on the basis of a man-hour rate is not very much better, although, as I shall point out later, that plan works very well for fitters and assembly men. To secure a correct burden distribution it is only necessary to prove, by analysis, the elements of which it is composed and then to consider how all this overhead is actually applied to the product.

At this point we encounter another mistaken tradition of *departmentalised costs*. To define burden correctly in each department is good as far as it goes, but it does not go very far, especially in a machine shop. The attention of the manager and the cost accountant ought to be fixed on the individual production centre, usually a power machine. Recent developments under actual shop conditions show that the correct burden for a machine tool may vary from less than 10 to over 300 per cent. of a machinist's wages. The widely-accepted method of charging burden to costs on the value of productive labour makes no distinction between the mechanic at the bench, whose work has practically no burden except supervision, and the operator using a costly machine, which involves heavy charges for maintenance, power and repairs.

The work of bench hands and mechanics on the erecting floor must be accompanied by a burden charge which obviously is not literally a machine-hour rate. The burden rate for bench equipment differs not at all in principle from the rates for the machine tools. If, as is usually the case, the mechanics at the bench work under substantially uniform conditions a uniform rate may be made at so much per hour for the use of the accommodations which they require for their work. In a large shop the bench rate might be different in different departments. Since it is uniform for all mechanics who work at the bench, it is practically a man-hour rate. It must be borne in mind, however, that it is a rate for the use of equipment only, unless indeed the circumstances make it convenient to merge the cost of supervision with the cost of equipment.

The erecting hands in a shop present a problem of a different kind. Their work usually requires a considerable area, and important charges for crane service and supervision. To speak of this work in terms which have long been familiar in cost accounting practice, the erecting floor may be considered as a department whose burden is to be distributed with reference to the work performed by the mechanics employed in the department. Probably the best way to distribute this burden is on a man-hour rate derived by dividing the total annual burden by the number of man-hours for the department.

There are other charges connected with the management of a machine shop or manufacturing plant which are not necessarily well expressed through an hourly equipment rate. Such are charges for the drawing-room, the book-keeping, cost accounting, supervision, liability insurance, and general charges of management not specifically and directly connected with the maintenance and operation of machinery. These are charges which in a small shop should be applied in a fairly uniform way over all the employés in the establishment, preferably on a man-hour basis. This charge would be known as general burden, and since it would be uniform, it may be applied to the cost of each job, against which hours of mechanics' time have already been recorded, with very little additional work.

The successful operation of a scientific machine rate is the most important development that has occurred in cost accounting practice in a generation. As these rates may be applied to the cost of jobs, the charge for burden which hitherto has been the difficult and uncertain part of cost accounting will be as accurate as the charge for direct labour. Furthermore, the use of equipment rates, in effect a precision method for the important part of overhead expense or burden, requires no more work in a cost office than the application of a rate which contains only part of these charges.

There are two good reasons for saying that a scientific machine rate is a development of tremendous importance in cost accounting practice. The first is that referred to previously, namely, that it is essential when scientific management is introduced that there should be an *exact* measure of the saving which is effected by it. The literature on this subject has not thus far made a sufficient recognition of the very important fact that if an operative reduces the time on a given job from ten to seven hours, for example, he has not only saved three hours at his wage rate, but also three hours at the rate for the machine tool which he has used, and three hours of general burden.

Cost accounting practice which analyses burden charges would naturally make a precise account of the increases in overhead expense of any kind. In some cases in connection with the introduction of scientific management, these increases would be in a particular department, and would operate to increase the burden which would be disposed of as a machine-hour rate for the tools in that department. Usually, however, the additional charges would operate to increase the general burden, which is one of the most important and at the same time one of the most elusive elements of manufacturing cost.

The second reason for attaching so much importance to a scientific machine rate is that it makes possible an accurate measure of the loss due to slack production or interrupted operation. This is perhaps more important than the improved accuracy of cost records referred to. When the board of directors is gathered at the end of the year, or once in six months, to learn about the results of the period under review, they do not often consider detailed matters as the cost of individual orders. On the other hand, they are always interested in any explanation which the manager has to make about losses that are due to curtailment of manufacturing operations.

The directors at such times would value more than anything else a clear statement showing how much their company had lost on this account, especially if the details of the statement could be readily understood and readily proved by an analysis of the operating conditions. The big problems in regard to manufacturing which the directors have to settle are to make an efficient use of plant and equipment, especially if they are asked to decide on new additions to meet a probable volume of business. The new plant means an added investment, and it is of the utmost importance that the account should subsequently show to what extent this investment was utilised.

It is essential to distinguish clearly between losses or gains on machines actually made and sold and losses due to slack production or inefficient use of equipment. It must be borne in mind that the finished product has absorbed only the burden of the equipment actually used in its manufacture. It has not absorbed the burden of unused equipment or idle machinery. If the plant includes a foundry and the management decides to purchase castings, the idle foundry has contributed nothing to the product. It is obviously unfair to charge into the cost of goods the burden charges on automatic machinery that may be idle because the management is buying and not making machine screws. If only three-quarters of the lathes run, the idle remainder have not helped machine parts actually manufactured, and although the plant may go into bankruptcy if it cannot utilise its equipment, the cost of the work actually done is not greater on that account.

The burden on idle machinery is no more a part of the cost of manufacture, unless due to enforced seasonal variations, than the burden on a shop owned by another corporation. When there is a proper distribution and application of expense burden, only the burden is charged to cost which represents the equipment utilised in manufacture, and burden not applied remains as a balance to be charged direct to the loss and gain account at the end of the month, six months, or a year. This is readily accomplished through the means of burden accounts which collect by a very simple book-keeping practice all of the charges in a given class, and receive credits as burden rates of the same kind and are charged to the cost of product going through the works. The unearned burden in some cases may indicate an error which is to be corrected by using a more accurate rate in a subse-

quent period, but when proper records have been established, the unearned burden is a clear loss, and the balances of the burden accounts should be transferred directly to the profit and loss accounts.

If the distinction is maintained between losses or gains on goods made and sold, the losses due to restricted output, the management will consider sales policies in a much more certain way than is ever possible when the facts are obscured in the haze of average costs, calculated in varying volumes of product. In respect to burden it is frequently true that costs figured as averages vary beyond all hope of comparison as the volume of output goes up or down. Whatever the effect on sales policy, good cost accounting, including correct burden distribution, is a matter of enduring importance from the point of view of manufacturing. Changes in volume may completely obscure gains or losses in efficiency, and render comparative costs in similar jobs impossible from season to season, solely because of the variations in the amount of business done. Exact costs, comparable under all conditions, are not to be secured unless the burden charged to production is only that pertaining to the equipment that is actually at work.

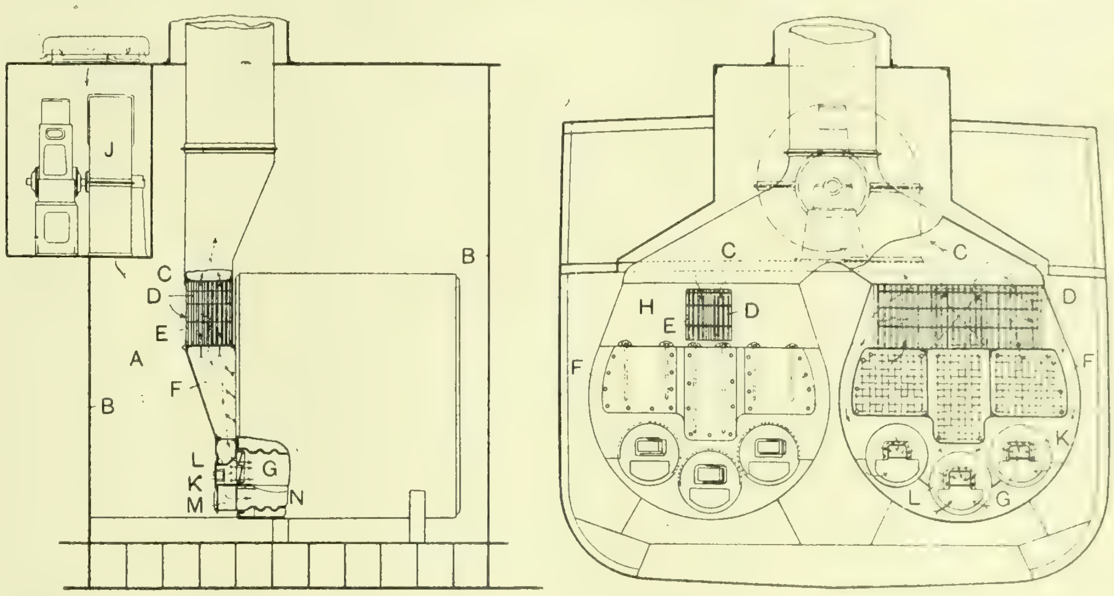
From the manager's point of view, the significant fact is that burden, which it is proposed to apply through a series of equipment rates, is not appreciably less when the operating schedule of the plant is reduced. It is true that power charges may be slightly less, but the fixed charges for building space, interest, insurance, taxes, depreciation, and under some circumstances for repairs also, are no less when the machines are idle. The manager of a machine shop cannot make a greater mistake in figuring costs than to charge a higher burden in any form whatsoever for the operation of part of his equipment, because the rest of it is temporarily idle, or a higher rate for a smaller labour force because the plant is working on part time. These differences, which have always attracted the attention of observing managers, are almost entirely clear loss or waste, and should be recognised as such and charged directly to the profit and loss account.

Perhaps the best thing that can be said about cost accounting practice by machine-hour methods is that it does not require any more work than any of the older methods that have been well developed as a means for taking out costs. Of course, if a plant with an under-developed cost practice, or none at all, starts to make improvements in a wholesale way, they must expect to increase their overhead charges. If this increase is wisely planned, it is sure to be a money-making expenditure. There are some conditions, of course, under which a machine rate cannot be used to distribute burden, but the underlying principle of collecting all burden charges for each production centre is sound, whatever method may be used for distribution. Some operations can best use a process rate, which includes labour and accessory supplies as well as burden. This method is particularly applicable to mass production, or any work that is not made on successive and clearly distinguished manufacturing orders. The application of overhead charges, however, can be made through a process rate strictly in accordance with approved principles of burden distribution.

Automatic or semi-automatic machines present a troublesome problem of burden distribution, especially as the burden is usually far more important than the labour as an element of manufacturing cost. This problem has been handled at a plant operating several hundred automatic machines by a plan of efficiency charts which provide for charging to the job the cost of the effective operation of the machine. Cost accounts under this plan measure with great precision the loss due to slack production or careless attention from the operator.

HOWDEN'S FORCED DRAUGHT INSTALLATION FOR SHIPS.

THE accompanying illustrations show a forced draught installation for boiler furnaces arranged in a closed stokehold, the invention of Messrs. James Howden & Co., Ltd., 195, Scotland Street, Glasgow. The cuts show the arrangement applied to boilers of the cylindrical type, but it is equally applicable to water-tube boilers. The boilers are equipped with an air heater located in the uptake or smoke stack, as usual in the Howden forced draught system, and are installed in a closed stokehold, the air heater being provided with an opening communicating with the closed space of the stokehold into which air is introduced under pressure in the usual manner. With this arrangement air pipes are entirely dispensed with, while the joints of the casing through which the air passes from the heater to the furnace do not require to be thoroughly air



HOWDEN'S FORCED DRAUGHT INSTALLATION FOR SHIPS.

tight, as leakage of air is practically impossible owing to the pressures inside and outside of the air casing being substantially equal. Further, with open stokehold forced draught installations it is necessary to provide valves in the furnace front for regulating the admission of air to the furnace above and below the grate, with mechanism interlocking the valves and the fire door in order to prevent back flame in the event of the fire door being opened while air is being forced into the furnace. Such valves and interlocking mechanism are dispensed with in the present arrangement.

Referring to the illustrations, the boilers are located in closed stokeholds A between the water-tight bulkheads B. In each uptake C is arranged an air heater which is composed of a nest of tubes D through which the hot furnace gases pass on their way to the smokestack. The space around the tubes forms part of an air duct or chamber F communicating in the usual manner with the furnace G. In the wall of the casing H enclosing the air heater tubes, is provided an opening E communicating with the closed stokehold space A. By means of a power-driven fan J air is introduced under pressure into the stokehold, and as the latter has no outlet save for the opening E in the air heater casing, the air is forced to pass through this opening and around the tubes, by contact with which it becomes heated into the air duct or chamber F and thence through perforations K in the fire door casing L to the furnace G above the grate, and by the entrance M into the ashpit N.

FAILURES OF HEAVY BOILER SHELL PLATES.*

BY SIDNEY A. HOUGHTON, A.M.INST.C.E. (SHIP AND ENGINEER SURVEYOR, MARINE DEPARTMENT, BOARD OF TRADE).

(*Continued from page 461.*)

Class B.—The failures of this class are in some respects of a more important character than those already considered, as the plates failed by cracking right across in the rolls, giving the impression of extreme brittleness.

B1.—This plate had only partially been bent to the required radius when it broke nearly across, there being two cracks in approximately the same line, which were only separated by a small web of metal. The tensile tests from this plate all give good results, and the chemical analysis is not abnormal, except that the quantity of phosphorus is high and greater at the outside than in the inside. The structure of the steel showed an excessive number of blow-holes (see Fig. 14), so that before etching the metal looked in parts more like wrought iron than steel. As might be expected from the analysis, there were also considerable local segregations of phosphorus at the outside, and, considering their amount and well-known want of ductility, they probably constituted the principal cause of failure. The plate was also rolled hot on one side, and on examining the sections at the fracture after light etching, lines were seen on the ferrite crystals which were at first thought to be slip bands, but on examination at higher power were found to be Neumann's lines (see Fig. 15). This plate and B4 are almost the only ones in which the author has seen these lines, and in both cases the metal was hard to the file, more so than would appear from this analysis. It is suggested that the ferrite contained arsenic or some other hardening constituent which was not analysed for.

B2.—This plate cracked right across in the rolls during the first pass. It had been cross rolled, so that the longitudinal axis of the ingot was the transverse one of the plate. The metal generally was of excellent quality, but from the fact that some segregation showed on one side of the plate and blow-holes at the other it is evident that too great a portion of the ingot was used. The number of these blow-holes was very considerable, and the structure on this side of the plate was of a coarse crystalline character, indicating it had either been overheated when being annealed and possibly piled afterwards, or that annealing had been insufficient to break down the rolling structure; on the whole the former would appear to be the correct opinion. Also at this side the effects of shearing had not been entirely removed by planing, but the structure only appeared to be distorted on the inside of the plate, as the edge had been bevelled as usual. A noticeable feature about this plate was the increase of pearlite on the outer surfaces, and it is suggested that this might be due to the effect of an excessive amount of composition on the ingot mould. In this connection it may be mentioned that heavy carbonisation of the surface may take place in large steel castings when certain carbonaceous coatings are given to the moulds, which fact does not seem to be so widely known as is desirable, and it is worthy of careful consideration by the users of such castings. The increase was comparatively slight in this instance, but would produce an appreciable effect when the plate was being bent. The most striking feature revealed by this case was the great importance of uniform annealing at a correct temperature.

B3.—The carbon content of this plate was too much, indicating that little work was given to the steel; the finishing temperature was very high, and there was considerable difference between the structures on opposite sides. There was also segregation in the centre of the plate and a large number of blow-holes near the surface, so that altogether the metal might be described as unsuitable for the purpose for which it was intended.

B4.—This plate broke completely across when being passed through the rolls for the first time, the fracture being of a coarse crystalline character. The tensile tests were on the whole satisfactory, only two of the transverse tests showing segregation, which, however, did not reduce the elongation below 24 per cent. The analysis shows high carbon and phosphorus, both being in excess of the amount suitable for mild steel. In preparing the sections it was noticed that the metal was very hard to file, and the structures revealed were found to be of an unusually interesting kind. Towards one side of the plate the ferrite crystals were of a large rounded form, whilst the pearlite was of a very ropey nature, some of it being in the form of cementite. This is shown in Fig. 16, the section being etched with boiling sodic picrite, which, as is known, blackens cementite and only shades the pearlite. This structure has been shown some years ago by Dr. Stead and more lately by Dr. Rosenhain to be formed when mild steel is kept at a temperature between 600° C. and 700° C., the structure thus produced being of a brittle nature. In this instance the effect was obtained in the annealing furnace, owing to the pyrometer being out of order. On the other side of the plate this formation did not exist, but the structure was very coarse and angular, and indicated that the plate was rolled too hot, and that the temperature of the annealing furnace was insufficient at that side to break it down. In the sections examined from the first-mentioned side many of the crystals near the fracture showed well-marked Neumann's lines (see Fig. 15). It may also be mentioned that in one section there were signs of "cupping" in the centre of the plate. The segregation was not excessive, and was exactly

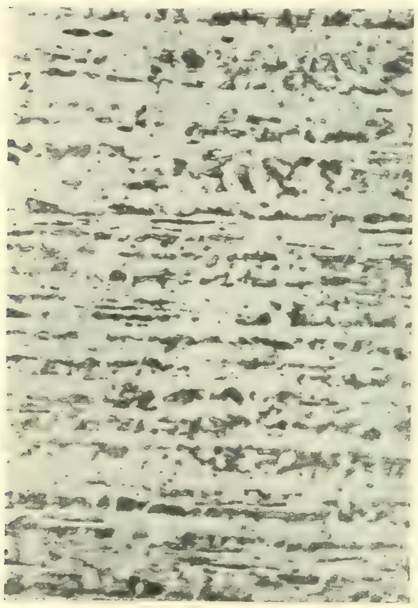


FIG. 14.—MAGNIFIED 50 DIAMETERS.

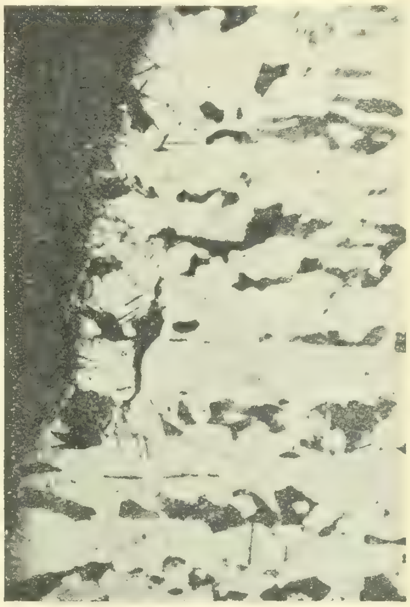


FIG. 15.—MAGNIFIED 200 DIAMETERS.

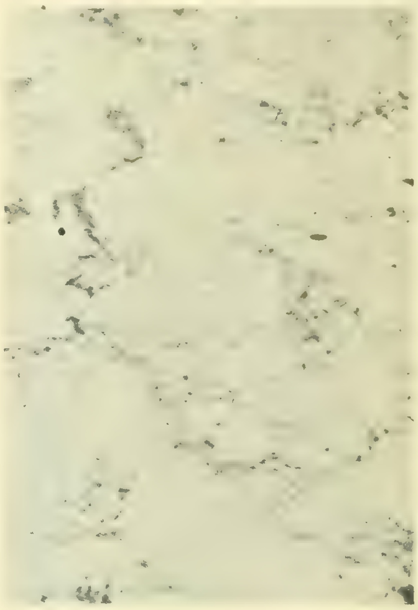


FIG. 16.—MAGNIFIED 300 DIAMETERS.

* Paper read before the Iron and Steel Institute, May, 1914.

in the centre of the plate, so that it was not at first discovered in examining the sections, as it was removed by the saw when cutting the complete section in half. The chief causes of failure appear to be the formation of a brittle structure combined with unequal annealing and high phosphorus.

Class C.—The failures under this heading are the most serious of all, seeing that they imply that the actual factor of safety of the shell was less than two.

C1.—In the first case to be considered the boiler was made with two strakes of plating, and the strake containing the manhole cracked right across through that part near the minor axis, when the hydraulic pressure had reached $1\frac{3}{4}$ times the working pressure, although it is said that twice the working pressure had been previously applied. It was found that the width of the manhole on one side of the fracture was $\frac{1}{8}$in. greater than the other side; but the manhole ring was intact, though the crack was open $\frac{1}{8}$in. on each side of the opening. The tensile tests all showed a tonnage below the original ones, and the transverse tests in line with the manhole showed a heavy central segregation which apparently extended to the manhole. The chemical analyses revealed a considerable difference between the centre and the outside of the plate, and at the former part the quantities of sulphur and phosphorus are excessive, as might be expected from the segregation shown by the transverse tests. The amount of arsenic is also very high, and this has segregated with the phosphorus. An examination of the structure confirmed the chemical analysis, the carbon being low at the surface, where there were some blow-holes and carbonless bands (see Fig. 17). Towards the centre there were some large compound crystals, and the structure became lamellar with increase of carbon, while at the centre there was heavy segregation. In this plate the segregation must have been an important element in producing failure, but probably the principal factor was the presence of internal stresses in the plate. It is difficult to estimate what proportion of these was due to rolling and what proportion to the manhole riveting, but on the whole it seems not unlikely that they were about equal.

C2.—In this instance the hydraulic test had reached about 40lbs. below the double pressure when the shell plate gave way at the manhole with a sharp report. The main crack extended from the manhole to one of the rivets in the circumferential seam, and was open $\frac{7}{64}$in. at the manhole and $\frac{1}{16}$in. at the seam. There was a small crack on the other side of the manhole extending only to the nearest rivet hole, and it was noticed that the caulking of the ring was undisturbed. This ring was of the flanged description, which requires a considerably larger opening in the shell than the plain variety, and is more difficult to fit accurately, so that the author thinks that the opening of the plate after the failure was more due to stresses set up in riveting than to any resulting from rolling. It is also more difficult with this form of ring to arrange that the actual compensation approaches the theoretical. The longitudinal tests of this plate were satisfactory except that near one end they were below the specified minimum—30 tons; but the transverse tests, taken from the centre of the plate, between the manhole and the other end, gave very inferior results, the elongation falling to 4 and 5 per cent. with a square fracture having a white line in the middle, which clearly indicated segregation. On examining a section this was found to be of a very fine typical character, and the author made the continuous photograph (Fig. 18) which shows the structure from the surface of the plate to the centre (a distance of $\frac{1}{16}$in.), where the carbon must be fully 0·8 per cent. It will be seen in the photograph that there are in places conglomerations of crystals which would not show at a moderately high magnification. Before etching a number of sulphide of manganese flaws were also evident at the centre. It is clear that the plate contained the major segregate of the ingot, and as the weight of the plate is not heavy compared with that of the ingot, it is probable that the segregate would not have been included unless a larger amount than usual had been cut off the bottom of the ingot, possibly to clear some defect. The steel of this plate was evidently defective, yet in the author's opinion the causes of this important failure must be considered as largely mechanical, as the segregation did not extend to the crack itself.

C3.—This case is of an exceptionally interesting character, as the plate fractured under the hydraulic test, not through the manhole itself but through the rivet holes at one end of the ring, the pressure at the time being at a little under twice the working pressure. There was only one strake of plating in the boiler, the manhole being rather near the back end, and it had a plain ring double riveted. The plate fractured from end to end, the crack passing through four rivet holes, at which place the edges were open $1\frac{1}{8}$in.; the distance diminished gradually towards the ends. At the manhole the edges were also sprung outwards $2\frac{1}{4}$in. The analysis from the metal near the manhole showed nothing unusual, but as the microscope revealed a large structure with segregation at

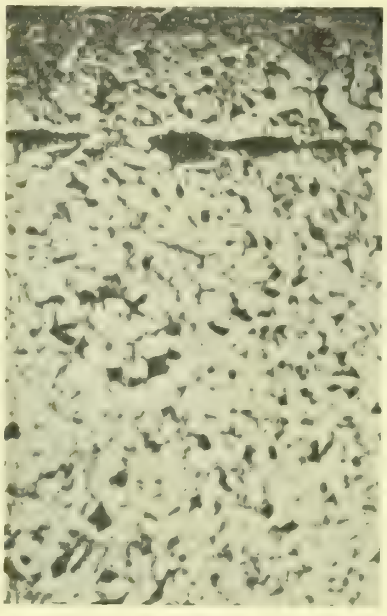


FIG. 17.—MAGNIFIED 50 DIAMETERS.

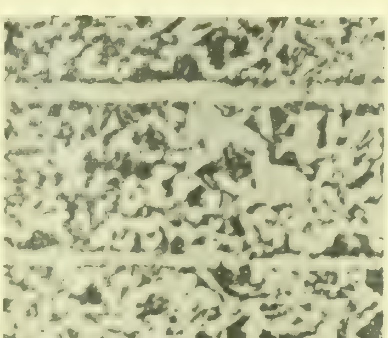


FIG. 19.—MAGNIFIED [illegible] DIAMETERS.

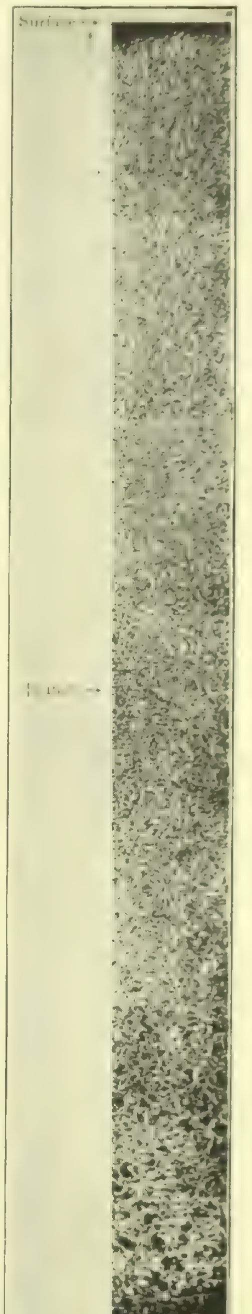


FIG. 18.

the centre (see Fig. 19), it would seem that the drillings for the analysis must have been taken near the surface. Seeing that the manhole was not in the longitudinal axis of the plate, it is probable that the segregation at that part would be heavy unless the plate had been cross-rolled. One of the transverse tensile tests taken near the fracture broke with a very low tonnage owing to the presence of a small crack, and another gave only 18 per cent. extension in 5in. owing to segregation; but the others gave satisfactory results, and the fracture itself showed no additional cracks. Some notched bar tests gave poor results—three and five blows—and on

TABLE II.

Class and Number.	Thickness of Plate.	Weight of Plate.		Weight of Ingot.		Percentage Weight of Plate of Weight of Ingot.	If Annealed.	Tensile Tests.			Chemical Analysis.						Structure.	Photograph. Fig. No.	Nature of Failure.	Probable Causes of Failure, with Estimated Percentage Values.
									Tons per Sq. In.	Elongation in 8in per cent.	Carbon.	Manganese.	Sulphur.	Phosphorus.	Silicon.	Arsenic.				
	In.	Tons.	Cwt.	Tons.	Cwt.															
B1	[illegible]	5	6	7	18	67·0	No.	Original*	30·3	24	0·23	0·52	0·037	0·072	0·04	—	Fairly uniform, but abnormal amount of blowholes. Many carbonless bands. Neumann lines.	14	Cracked almost across in rolls.	Segregation of phosphorus on surface (40); excessive phosphorus (25); abnormal number of blowholes (20); high finishing temperature on one side (15).
								At fracture, long.†	28·0	30	0·21	0·51	0·034	0·06	0·04					
								At fracture, trans.	27·4	30										
B2	[illegible]	7	14	17	0	45·3	Yes.	Original	32·8 to 30·5	23 25	0·22	0·74	0·032	0·048	0·068	0·018	Increase of carbon at surface. Coarse angular structure on one side, with large number of blowholes.	—	Cracked right across in rolls.	Stresses produced by unequal heating (40); excessive rolling temperature on one side (20); increase of carbon at surface (15) blowholes (10); shearing effect (10); segregation (5).
								At fracture, long.	32·0	30										
								At fracture, trans.	29·3	22										
B3	[illegible]	4	5	7	10	56·6	No.	Original	31·3	22·5	0·3	0·52	0·03	0·055	0·03	—	Heavy blowholes near surface. Large number of compound crystals; segregation.	—	Cracked right across in rolls.	Plate rolled too hot (15) and different temperatures at sides (40); segregation (20).
								At fracture, long.	30·8	25										
								At fracture, trans.	31·7	24										
B4	[illegible]	5	6	7	17	67·5	Yes.	Original	28·8	29	0·27	0·55	0·043	0·061	0·045	-	On one side pearlite, ropey, and partly changed into cementite; on the other coarse angular, Neumann lines; segregation.	15, 16	Cracked right across in rolls; fracture coarse crystalline.	Annealing at improper temperature (30); unequal temperature in annealing (20); rolling too hot (5); high phosphorus (25); segregation (10).
								At fracture, long.	31·4 to 28·9	30 29·5										
								At fracture, trans.	28·9 to 31·7	28 24										
C1	[illegible]	4	3	—		–	No.	Original*	29·6	26	0·152	0·517	0·044	0·051	0·03	0·025	Carbonless bands at surface; carbon low at surface, segregation in centre; many compound crystals.	17	Cracked through manhole during hydraulic test.	Internal stresses (35); stresses from riveting ring (35); segregation (25); rolled too hot (5).
								At fracture, long.†	28·4	27	0·24	0·542	0·078	0·088	0·023	0·055				
								At fracture, trans.	28·5 to 25·6	25 8										
C2	[illegible]	4	10	9	18	45·4	No.	Original	31·5 to 30·5	26 20	0·22	0·57	0·033	0·046	0·016	—	Structure at crack fairly normal. Severe segregation beyond manhole.	18	Cracked through manhole during hydraulic test.	Stresses from riveting ring (55); internal stresses from rolling (20); segregation (25).
								At fracture, long.‡	32·0 to 28·2	20 33	0·25	0·57	0·037	0·051	0·014	outside				
								Near manhole, trans.‡	26·6	5	0·35	0·62	0·05	0·07	0·016	inside				
C3	[illegible]	4	14			—	No.	Original	29·2	29	0·17	0·57	0·03	0·05	0·03	0·02	Considerable amount of compound crystals, central segregation, otherwise normal.	19	Cracked right across through manhole rivet holes during hydraulic test.	Stresses from riveting ring (55); internal stresses from rolling (25); segregation (15); rolled rather hot (5).
								At fracture, long.	28·6	27										
								At fracture, trans.	27·7	18 in 5in.										
C4	1	4	1	6	2	67·0	No.	Original	28·3	25	0·195	0·524	0·52	0·05	0·008	—	Many compound crystals. Carbonless bands ⅛in. from surface, porosity in centre.	20, 21, 22	Cracked through solid plate during hydraulic test.	Plate rolled too hot (30); segregation (30).
								Near fracture	30·6	28·7 in 2in.										

* Surface. † Middle. ‡ Segregated part.

annealing the specimens with slow cooling this number increased to 26 and 18. On the whole the tests and examination do not show that the metal was sufficiently inferior to cause failure, and it is, therefore, to a large extent a question of internal stresses, whether produced by rolling or riveting. The fact that the plate failed in a part near the manhole where the strength was but little reduced points to some cause arising from the riveting. The author is therefore inclined to believe that, as will be explained later on, the chief stresses in the plate were produced by riveting the end rivets, and then working from the other end of the ring towards the part where failure took place.

C4.—This plate was made by the basic open-hearth process, and is the one referred to by Mr. Milton in his paper, the material of which was thoroughly investigated by Dr. Arnold, the report made by him being given as an appendix to the paper. The author only includes it here therefore for the sake of comparison, but as he had several pieces of it given to him by Mr. Milton, a few observations may not be out of place. It should be stated that this plate fractured right across through the solid metal under the hydraulic test. Dr. Arnold concludes that the plate had some abnormal thermal treatment in the mill which made it brittle; if, as would appear from his previous remarks, this was caused by overheating the slab, the author is in entire agreement with him, as many of the sections showed considerable amounts of compound crystals (see Fig. 20), and considering that the plate was only 1in. thick it seems probable that as the finishing temperature was high the slab itself must have been grossly overheated. In some other sections examined by the author there were some carbonless bands a quarter of an inch from the surface—a very unusual place—and porosity at the centre. The ferrite crystals were extremely soft, and in polishing the metal gave an appearance of slight porosity which was absent from the acid steels dealt with in this paper. As stated by Mr. Milton, the plate was compared with a similar one made by Messrs. Spencer & Sons, of Newburn. The author made the following simple experiment with a fatigue test-piece from each plate; the two pieces were placed close together and heated to a bright red, and then allowed to cool together. Figs. 21 and 22 show the structures thus obtained, the differences being remarkable. The causes of failure of this plate were not wholly defined by Dr. Arnold, and this exemplifies the great difficulty an investigator experiences when he is not able to see and select his own tests from the fractured plate. It may be added that the weight of the plate as cut was 67 per cent. of that of the ingot, so that it would probably contain the major segregate, which fact may explain the great differences Dr. Arnold found in a second piece sent him, and may have had an important influence in causing the failure.

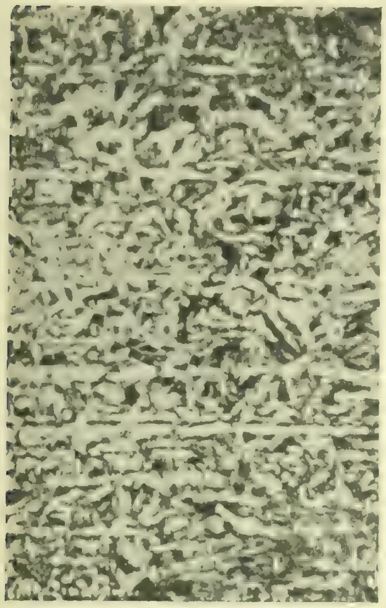


FIG. 20.—MAGNIFIED 50 DIAMETERS.

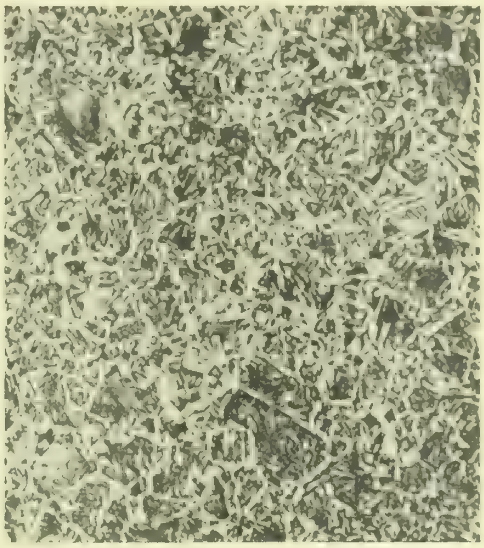


FIG. 21.—MAGNIFIED 50 DIAMETERS.

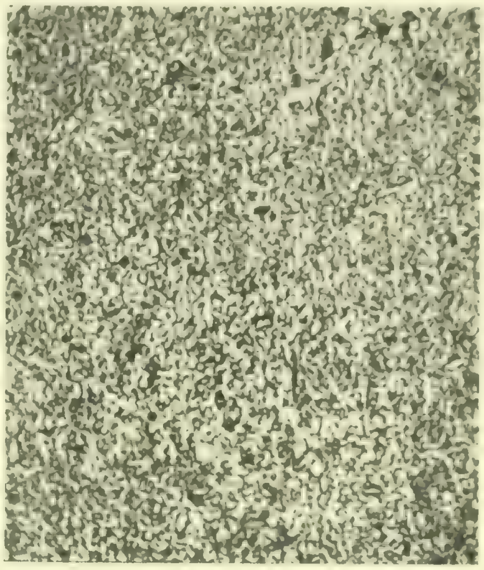


FIG. 22.

It will be noticed that the longitudinal tensile tests, even when taken near the fractures, seldom revealed any abnormal features, whilst the transverse tests were far more successful, and so far as tensile tests go these are certainly the most valuable for ascertaining the inferior parts of steel plates. In nearly all the cases dealt with the bend tests were satisfactory, and at first sight it seems somewhat of an anomaly that a piece of a plate can be bent through 180°, whilst the whole plate fractures at a very slight angle. The conditions are, however, wholly different, as in a bend test the metal can flow with little restriction, whilst in the plate very little lateral flow is possible. Fig. 23 shows the distortion which takes place in an ordinary bend; it can be readily seen that the relative contraction and expansion of the two sides diminishes in proportion as the width of the bend is increased, and that in a plate the metal is subjected to pure stretch and compression. This fact is of special importance in considering the effect of hammer dressing, as though it is frequently possible to bend a strip of steel after being hammered on the outer surface, it does not therefore follow that hammering a wide plate would be equally innocuous.

In dealing with these cases it is essential to remember that one cause of weakness does not prevent others, and that in general it is the simultaneous occurrence of several defects which results in failure. For instance, it is not sufficient to say that a plate failed because it was segregated; there is little doubt that there are many more or less segregated plates in boilers, but they have not failed as no other diverse conditions were present. A good plan in dealing with a failure is to estimate the percentage value of the different causes producing the fracture, and this has been done in Tables I. and II., but it will, of course, be understood that the values are only approximate estimates. When the total does not reach 100 it means that the author does not consider that all the causes have been ascertained.

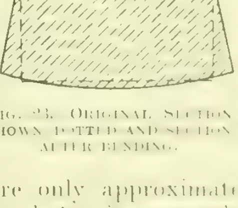


FIG. 23.—ORIGINAL SECTION SHOWN DOTTED AND SECTION AFTER BENDING.

In many cases hammer dressing is given as one of the causes, and this is something which one might have hoped would have ceased long ago. Unfortunately it frequently happens that a little hammering saves a good deal of chipping and buffing, and the temptation to use the first-mentioned tool is considerable. Moreover, it is almost impossible to detect it if the plate is buffed afterwards, and of this fact the loading bank staff are generally aware, so that very stringent orders and constant superintendence are necessary to prevent it being done. In point of fact the only certain method of

detecting it is to examine a section of the plate after fracture occurs, when it is generally plainly evident. The surface defects which necessitate dressing may be only roughness caused by scale being rolled in, or they may be of a more serious nature in the shape of laps, snakes, &c., or due to the local segregations of phosphorus, which cause the "ghosts" in forging. The latter are probably the worst defects, and as can be seen in Fig. 5, must seriously reduce the ductility of the plate as regards bending; they may also tend to give a rough surface in rolling by sticking to the rolls, and will assist in causing corrosion when the plate is in the boiler. The nature and origin of these local segregations have been dealt with by Dr. Stead in a lecture on "Phosphides and Carbides in Iron," and it is to be hoped that steel makers will endeavour to produce ingots for such important plates with a minimum amount; probably the best plan is to keep the phosphorus content as low as possible.

Dressing plates, as now done with an electrically driven emery wheel, is *per se* generally supposed to produce no bad effect, and probably this is true if only the surface is cleaned. If, however, an extensive deep defect, produced, say, by scale being rolled in, is removed, it is quite conceivable that when the plate is bent local stresses are produced, seeing that the resistance to bending varies as the square of the thickness. These stresses may be serious in amount, and in some cases may be even one of the primary causes of failure.

(To be continued.)

THE WORKS OF THE BRITISH OXYGEN COMPANY, LTD.

On Saturday, May 9th, a party of members of the Institute of Marine Engineers paid a visit to the works of the British Oxygen Company, Ltd., Elverton Street, Westminster. In 1886 the company commenced the manufacture of oxygen by the barium-oxide process. Seven or eight years ago apparatus was installed for the production of oxygen by the liquefaction of air, and after running the two processes for a while, the barium process was at length entirely superseded and all the oxygen now produced by the company is obtained by the liquid air process. During recent years the demand for oxygen has considerably increased, chiefly due to the general adoption of the oxy-acetylene process of metal cutting, welding, &c., the company now supplying from their different works throughout the country upwards of 1½ million cubic feet per week. In the Westminster works there are two liquid air plants in operation, one capable of producing about 500 cub. ft., and the other 1,000 cub. ft. per hour. Economy of space being an essential consideration, Diesel engines have been installed for driving the plant, of 40 b.h.p. and 80 b.h.p. respectively.

The air is first purified by being drawn through tanks containing caustic soda. It is then compressed by means of a 3-stage belt-driven compressor, the pressures at the different stages being 40lbs., 400lbs., and 1,000lbs., approximately. Inter-coolers are provided to keep down the temperature, and before the air is passed into the separator it is further reduced in temperature and all traces of moisture removed by means of high-pressure dryers containing calcium chloride and a CO_2 cooling apparatus, on leaving which the air is considerably below the freezing point. It then passes down to the separator, which consists of a suitable case containing a series of spiral coils, or temperature interchanger, through which the pre-cooled compressed air passes on its way to the expansion point near the bottom of the separator. Within these coils is placed the rectifying column (or central tube) and the container for collecting liquid oxygen.

The compressed air passes down the interchanger coils and through the liquid container to the expansion valve, where the pressure is allowed to drop. The air which has been cooled by expansion is then taken up and enters the rectifying column through the funnel-shaped opening near the top, leaving the separator through the large tube which connects the top of this column with the bottom of the outer tube of the interchanger. In this way the compressed air on its way to the expansion point is surrounded by colder air which is passing off through the coils in the opposite direction, so that the temperature of the compressed air is being continually lowered until it reaches the point of liquefaction. The air which now liquefies at the expansion valve, enters the top of the rectifying column by the funnel mentioned above. In falling through this column the temperature is slightly increased the more volatile nitrogen boils off and rises to the top of the column, from which it is discharged through the interchanger coils. The liquid oxygen, which collects in the container at the bottom of the separator, is allowed to evaporate slowly into the pipe leading to the gasholder, in which it is stored ready for compressing into cylinders. Liquid oxygen boils at 182·9° C., and liquid nitrogen at 195·8° C. It is therefore possible to separate the two gases by allowing the nitrogen to boil off at the lower temperature.

It is usual to employ two forecoolers and separators to ensure continuous working, for when ice (due to the untrapped moisture in the air) has accumulated to such an extent as to cause a blockage in one unit, the other can be put into operation while it is allowed to thaw. In practice this freezing up is found to occur after six or seven days of continuous work. A sample of the liquid oxygen was drawn off in a test tube, and on a piece of flexible rubber tubing being inserted it was immediately frozen and rendered rigid and brittle; a small quantity of the liquid poured into a pail of water at once produced a coating of ice. The compressors charging the oxygen cylinders work at a pressure of 1,800lbs. In order to obviate the use of oil in any form, the plungers are made of gunmetal and water lubrication is adopted. Every cylinder is periodically tested, the expansion and reaction of the metal under pressure test being indicated by a water gauge. All cylinders are annealed once in every four years.

Various kinds of apparatus for the use of oxygen are made on the works, in particular blow pipes for use in the oxy-acetylene processes, regulating valves for the use of oxygen in smoke helmets, diving gear, &c. A demonstration of oxy-acetylene cutting and welding was given, a piece of 5in. armour plate being cut through in a few minutes, and a weld effected in a piece of iron pipe. Refreshments were kindly supplied to the visitors and a vote of thanks was afterwards accorded to the company on the proposal of Mr. J. E. Elmslie, seconded by Mr. W. McLaren. The tour of the works was made under the guidance of Mr. S. M. Thomson and Mr. S. T. Clark.

Boiler Explosion on s.s. "Bull Dog."—The formal investigation ordered by the Board of Trade to be held in this matter is fixed for hearing in the Sessions Court, Law Courts, Hull, on Thursday the 4th proximo, at 11 a.m.

Tests of Aeroplane Engines.—Quite a number of manufacturers of motor engines have responded to the offer of the Government of a prize of £5,000 for the engine which comes out best in the series of severe trials which have been arranged to take place at the Royal Aircraft Factory at Farnborough. In addition to the premier prize £100 will be awarded to the makers of each engine which passes certain of the tests, while the Government will place orders to the amount of £40,000 with makers whose engines fulfil certain requirements. Altogether 29 different types of engines designed for aeroplane work have been entered, the horse-power ranging from 90 to 200, the first essential in each being that with the exception of the magneto every part is of British manufacture. The six types benched for the opening of the competition are a six-cylinder Argyll, 120 h.p., of the single-sleeve-valve type, the first attempt by this firm in aeroplane engine construction, and an eight-cylinder set in a double set of four at an angle of 90°, also a first attempt; an eight-cylinder E.N.V. engine of 100 h.p., an eight-cylinder White and Poppe of improved type; a seven-cylinder Dudbridge, 95 h.p., a French design but of all-British manufacture, the cylinders being set round a central shaft like spokes in a wheel; and an eight-cylinder Wolseley of 135 h.p. All are water-cooled, but some of the engines entered are air-cooled.

THE FLYING-MACHINE FROM AN ENGINEERING STANDPOINT.*

BY FREDERICK WILLIAM LANCHESTER, M.INST.C.E

(*Continued from page 466.*)

(3) *The Laws of Resistance.* Having established the general character of the airway, or track on which the flying machine is sustained, we pass directly to the consideration of the law of resistance, as determining the coefficient of traction on which depends the power expenditure. It is customary, and it is correct, to regard the resistance encountered by a machine in flight as made up of two parts firstly, the direct resistance, which varies approximately† as V^2, viz., that form of resistance common to flying machines, dirigibles, motor-cars, ships, &c., in other words, the ordinary resistance experienced by any vessel or body in its passage through a fluid; and, secondly, the flight resistance proper which follows an entirely different régime.

So far as the pilot or aviator himself is concerned all the direct resistances may be regarded as of the same kind and grouped together, viz., the sum of the eddy-making and skin-frictional resistances due to the fusillage, the alighting chassis, and the various struts, stays, and spars, whether belonging to the body of the machine or aerofoil; also the engine resistance (if exposed), the radiator, and the frictionally-exposed surfaces of the rudders, fins (vertical surface), and of the aerofoil itself. Resistance from all these causes varies approxi-

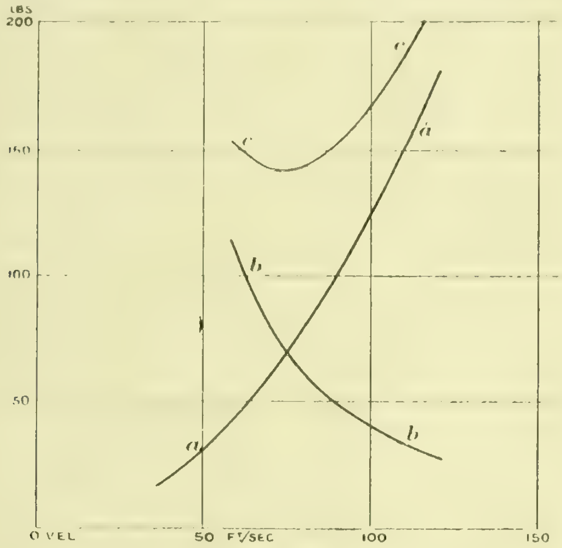


FIG. 11.

mately at V^2, and so can be represented by an equivalent normal plane, and this equivalent normal plane is one of the resistance constants of any given machine: it may be represented by a graph *a a* (Fig. 11)—a portion of a parabola—covering the range of speed of which the machine is capable.

From the point of view of the pilot the aerodynamic resistance *b b*, which goes to make up the total *c c* (Fig. 11), follows, within limits, the inverse square law, viz., varies as k/V^2, where k is a constant determined by the design of the aerofoil: there is a critical angle which defines the low velocity limit of this law, and at best the inverse square law is but an approximation: it is the correct law to assume for an undefined form of aerofoil, but every individual design has its own particular manner of variation, which must be ascertained by experiment. The experimental determinations for any aerofoil include, with the aerodynamic resistance, the skin frictional, and a certain amount of other inseparable direct resistance, so that if experimental values are taken these resistances should not be again included in the computation of the equivalent normal plane.

From the point of view of the designer things wear a somewhat different aspect, and a sharp line has to be drawn between two different classes of direct resistance. In the first place, there is the body resistance, which is taken to include the resistance of all those parts, such as fusillage, alighting gear, &c., which is independent of the design of the aerofoil. In the second place there is the direct aerofoil resistance, including the skin friction and strut and stay resistances, which are variables depending upon the area and span, and otherwise upon the design of the aerofoil itself. The designer can by sufficiently extending the aerofoil reduce the aerodynamic resistance (as shown by Langley) to as low a value as he please, within the limit prescribed by the question of the added weight; but this reduction in the aerodynamic resis-

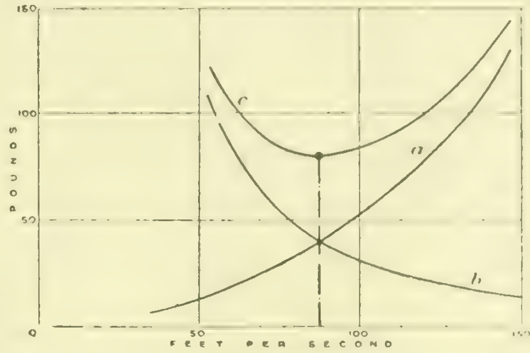


FIG. 12.

tance is accompanied by an increase of skin frictional and other direct aerofoil resistance, so that for any given machine and designed velocity there is an extent of aerofoil beyond which it does not pay to go: there is definitely a design of least resistance.

I have shown that, treating the matter from the broad standpoint of general theory, the condition of least resistance is reached when the aerodynamic and direct resistance of the aerofoil are equal to one another.‡ This is illustrated by Fig. 12, in which (as in Fig. 11) *a a* represents the graph of the direct resistance ($R \propto V^2$), and *b b* that of aerodynamic resistance ($R \propto 1/V^2$), and *c c* is the total (ordinates = resistance, abscissæ = velocity). In Fig. 13 a similar result is shown, in which the plotting is given for constant velocity (abscissæ = area), as representing more literally the problem as presented to the designer.

The general theory on which the foregoing result is based depends upon and is subject to the limitations of the $1/V^2$ law of aerodynamic resistance. This law corresponds to the straight-line law as correlating pressure and angle, and is a

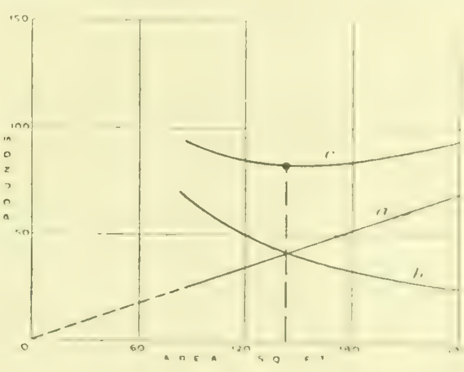


FIG. 13.

close approximation between useful limits, but breaks down at a certain critical maximum angle (depending mainly upon the aspect ratio), as shown in the examples given in Figs. 14A and 14B. The square plane follows a straight line law up to about 30°, in the plane of aspect ratio = 6: the limit is about 12°, the breakdown of the law at these limiting angles puts a very different limit to flying at low speed.

I have demonstrated that the condition of least resistance implies, for an aerofoil of any given aspect ratio, a

* The "James Forrest" Lecture, 1914, delivered before the Institution of Civil Engineers, May 5th, 1914.

† The V^2 law, it would appear, in no case exactly represents the actual facts; the departures from this law crop up in various and sometimes most unexpected directions. In the case of resistance due to skin friction sufficient data exist to enable the degree of departure from the law to be computed: in other cases, as for example, in the pressure reaction experienced by an inclined plane or aerofoil, departures of a different kind have been demonstrated, and are being gradually elucidated by experimental investigation. In spite of these shortcomings, the foundation theory of flight is to-day, and probably will continue to be, based on the V^2 law.

‡ "Aerial Flight," Vol. I., ch. vii.

definite value of the angle of trail*, β, Fig. 15; the chord angle, except where a plane lamina is used, is an accidental quantity, and not, as frequently supposed, one of fundamental importance; calculated values of trail angle β for least resistance are given in Table IV. Thus any aerofoil properly designed for least resistance for any given velocity of flight

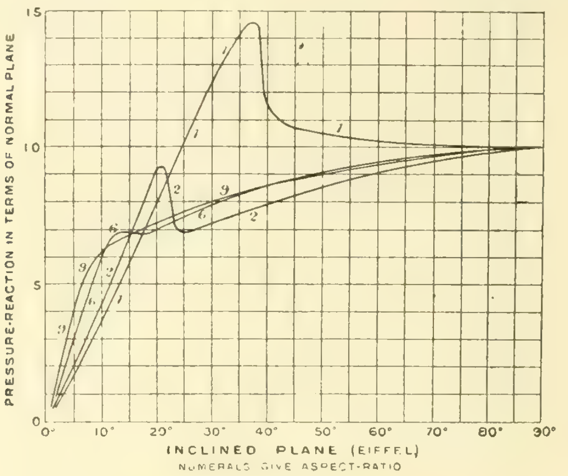


FIG. 14A.

TABLE IV.—*Values of β (Angle of Trail) for Least Resistance.*

Aspect Ratio.	ξ 0·020	ξ 0·015	ξ=0·010
3	0·189=10·8°	0·163= 9·3°	0·133= 7·6°
4	0·196=11·2°	0·169= 9·7°	0·138= 7·9°
5	0·202–11·6°	0·174=10·0°	0·142= 8·1°
6	0·206=11·8°	0·178=10·2°	0·145= 8·3°
7	0·212=12·15°	0·183=10·5°	0·149= 8·5°
8	0·218=12·5°	0·189=10·8°	0·154= 8·8°

will be correctly designed for every other velocity provided that its load per unit area be varied as the square of the flight velocity.

It thus becomes possible to prepare tables of mean pressure values proper to least resistance for different flight velocities and different values of aspect ratio (Table V.). Tables IV. and V. are reproduced from my "Aerial Flight," Vol. I., pp. 261, 262, and 271, the variable factors in addition to the flight-speed being the aspect ratio, which is here shown as tabulated for values from 3 to 8, and the coefficient of skin-

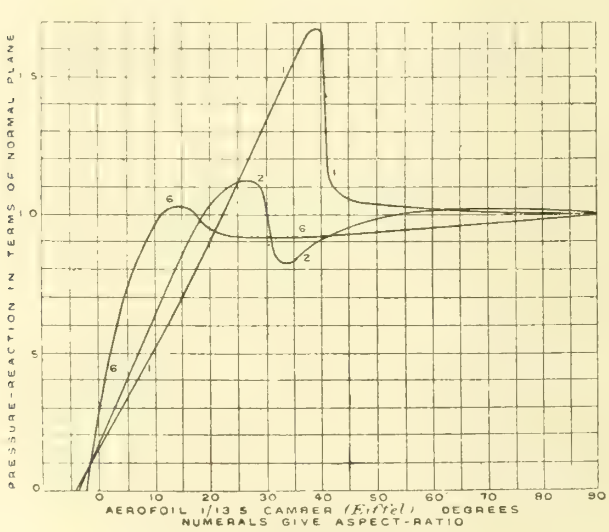


FIG. 14B.

friction values of which are taken from 0·01 to 0·02 double surface coefficient. These values for skin friction are on the high side, but as an actual fact the values given do fairly represent the total direct resistance that in practice depends upon the area of the foil, and which requires to be included in the useful application of the theory; the higher values, generally speaking, represent more closely biplane conditions, and the lower values are more applicable in the case of the monoplane.

TABLE V.—*Pterygoid Aerofoil.*

Load (pounds) per Square Foot for Least Resistance.

	Flight Velocity. Feet per Second.	Values of Aspect Ratio. 3	4	5	6	7	8
ξ=0·020	5	0·017	0·018	0·020	0·022	0·023	0·025
	10	0·068	0·075	0·082	0·089	0·094	0·101
	15	0·152	0·169	0·186	0·200	0·213	0·228
	20	0·270	0·300	0·330	0·355	0·379	0·405
	25	0·390	0·433	0·475	0·511	0·545	0·582
	30	0·610	0·676	0·743	0·800	0·852	0·911
	35	0·830	0·920	1·01	1·08	1·16	1·24
	40	1·08	1·20	1·32	1·42	1·51	1·62
	50	1·69	1·88	2·06	2·22	2·37	2·53
	60	2·44	2·70	2·97	3·20	3·40	3·64
	70	3·32	3·68	4·05	4·35	4·64	4·96
	80	4·33	4·81	5·30	5·70	6·07	6·47
ξ=0·010	5	0·012	0·013	0·014	0·015	0·016	0·018
	10	0·047	0·053	0·058	0·063	0·066	0·071
	15	0·107	0·119	0·131	0·142	0·150	0·161
	20	0·190	0·211	0·234	0·253	0·267	0·287
	25	0·298	0·331	0·366	0·396	0·418	0·450
	30	0·427	0·475	0·526	0·570	0·601	0·645
	35	0·582	0·647	0·717	0·777	0·820	0·880
	40	0·760	0·845	0·935	1·01	1·07	1·15
	50	1·18	1·32	1·46	1·58	1·67	1·79
	60	1·71	1·90	2·10	2·28	2·40	2·58
	70	2·32	2·58	2·86	3·10	3·27	3·51
	80	3·04	3·38	3·73	4·05	4·27	4·59

It would appear from recent experiment that my conclusions, as given in Tables IV. and V., though in the main



FIG. 15.

correct, require revision, at least, in a quantitative sense. Thus, plotting values of the pressure constant, as derived from Table V., for different values of aspect ratio, and as determined for the condition of least resistance (max. lift/drift) by the National Physical Laboratory (Fig. 17), we find the two in perfect agreement for aspect ratio=6; we also find that both graphs slope in the same direction, viz., they give a higher pressure constant as appropriate to higher aspect ratio; we do not, however, find justification for the extent of the difference as given in my table: the N.P.L. curve gives the effect as very slight indeed, in fact, almost negligible, the pressure constant for the aerofoil tested might be assumed as 0·32 for all values of aspect ratio without serious error.†

In Fig. 18, the N.P.L. curve from Fig. 17 has been plotted for comparison with the curve of the normal plane. It is well known that the pressure constant of the normal plane is greater for planes of elongate form; the normal plane curves given in Fig. 18 are based on the determinations of Langley and Dines, as given in "Aerial Flight" (the upper curve); and the more recent determinations of Mr. Eiffel, the values according to this authority being very much lower. On the left, on the line aspect ratio=1, we have the value for the square plane as determined by the N.P.L., and a curve is

* It is not easy to define the *angle of trail* of an aerofoil when the section is one of considerable body; clearly it is something intermediate between the upper and under surfaces, probably more nearly approximating to the former, as shown by the dotted line in Fig. 15.

† The series of observations from which the curve N.P.L. in Fig. 17 was plotted are those given in Advisory Committee Report 1911-1912, Memorandum 60, § vi, Plate 3; the section of the form of aerofoil used is given in the Report, and is reproduced in silhouette in Fig. 18. The value of the pressure constant (at maximum lift/drift) evidently varies considerably for different forms of section. Rejecting forms that may be considered bad on account of their low maximum, we find: In Report 72 (1912-1913) the fourth, fifth, and sixth sections given in Fig. 1, constants 0·322, 0·334, and 0·334 respectively. In the same Report, section ii., figures are given of the tests of four aerofoils varied as to bluntness of leading edge. The three best of these each had a constant approximately 0·4. In the same Report an aerofoil corresponding in form to "R.A.F. 6" gave a value almost exactly 0·3.

shown (dotted) directed towards this point as being the nearest we can at present do towards a representation of the truth.

The relation of the normal plane curve to the N.P.L. curve aforesaid is most suggestive; it happens that the values of the constants are almost exactly in the relation of two to one - this is probably a mere coincidence; a more important fact is that the increase of the pressure constant of least resistance (touching changes of aspect ratio) for the aerofoil is almost exactly proportional to the ordinary pressure increase in the case of variations of proportion in the normal plane. This suggests that the increase in the two cases is due to the same primary cause; also that the coefficients of camber proper to least resistance is a quantity independent of the

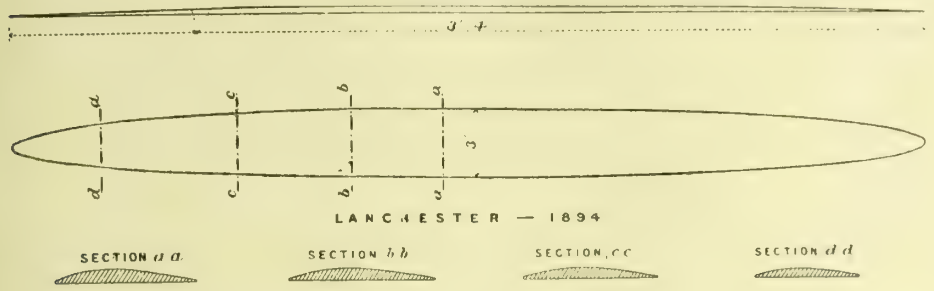


FIG. 16.

aspect ratio. If this should turn out to be the case the reduction of the resistance for aerofoils of high aspect ratio may be regarded as due entirely to the fact that, where the cyclic component is stronger, the dip of the leading edge can be increased at the expense of that of the trail, that is to say, the chord angle may be diminished with higher aspect ratio, and with it the trail angle will be also diminished. This is contrary to the tabulated results of Table IV.; if true, it must lead to the reconsideration of some of the assumptions on which I based my theory, or at least in the revision of some of the values of my constants.

In spite of the evidence, it is by no means certain that the matter is quite as simple as it appears. It is to be observed that any investigation to determine the effect of aspect ratio must of necessity involve a very complex experimental campaign, not merely a set of determinations with some half-dozen or so models sawn off to length from a piece of Blériot or de Havilland "mouldings"; this is exactly what was done in the experiments forming the basis of the plotting given in Fig. 17; any such method of investigation is liable to prove delusive.*

In the first place, each aspect ratio should be explored by a number of determinations using aerofoils of varying camber; secondly, the aerofoil section must not be uniform from end to end, the section must be "graded," or, as it is sometimes expressed, the camber must "wash out" at the extremities. Beyond this, not one series must be tried but some dozen or more. The final "winner" for each aspect ratio is the aerofoil of greatest lift/drift.

In my opinion, in the present unsatisfactory state of things, it is best (so far as the pressure constant is concerned) to assume a uniform value for all values of aspect ratio, say, that given as appropriate to aspect ratio = 6 in the Table V. Whether we consider the N.P.L result as valid or not, the salient fact is that we have at present no sufficient evidence that there is any change in the pressure constant worth taking into account. Alternatively we are not going far astray if we assume aerofoil pressures equal to half the pressure on the normal plane, as shown in Fig. 18.

The most important fact with which we are immediately concerned in connection with the theory of least resistance is that the total aerofoil resistance for least value is almost constant in respect of velocity: in other words, provided that we design for least resistance, we know our traction coefficient in advance: it is virtually a constant, just as though the problem were that of an automobile required to ascend a hill of known gradient an analogy which comprehends the fact that there is the direct wind resistance or body resistance additional in both cases. This constant is only within control inasmuch as by careful design the effective value of the coefficient of skin fraction ξ can be kept down, and a high aspect ratio adopted. Theoretical values of least gliding angle (that is to say, resistance coefficient), tabulated for values of ξ and aspect ratio, are given in Table VI.† It is of some interest to enquire to what extent these results are in agreement with modern experiment.

I have collected experimental data from various sources: a series of aerofoils of Blériot section,‡ aspect ratios vary from 3 to 8. Determinations of Voisin wing by Mr. Eiffel, aspect ratio 6·3. Aerofoil "R.A.F. 6" (Royal Aircraft Factory), aspect ratio 6. Aerofoils from my 1894 model, aspect ratio 13·3, Fig. 16, independent determinations by N.P.L. and Gottingen Laboratories. The above are given in Table VII.; columns 1, 2, and 3 give the aspect ratio, type, and authority, respectively; column 4 gives the experimental determination, and my theoretical values are given in columns 5 and 6 for values of $\xi = 0·02$ and $\xi = 0·015$. Table VII. is shown plotted in Fig. 19, the relation of aspect ratio to lift/drift being represented by curves drawn through the observed and calculated values.

It will be noted on referring to Table VII. and Fig. 19 that the agreement is almost complete. The two cases of the Eiffel determination of the Voisin aerofoil and the R.A.F. 6 aerofoil are shown as outlying points, not being fully in agreement with the main run of the remaining experimental determinations: it will be noted, however, that the whole of the experimental values lie between the two adjacent theoretical curves given, and the general form of the experimental curve corresponds to the curves given by my equations. It is true that there is something in the nature of the hump on the experimental curve, the extremities of which correspond to a double surface coefficient of skin friction of 0·02, whereas the central part of the curve round about aspect ratio = 6 rises nearly to the upper curve. This peculiarity of

TABLE VI.—*Least Gliding Angle* ($=\gamma_1$) (*Theoretical*).

n	$\xi = 0·025$		$\xi = 0·02$		$\xi = 0·015$		$\xi = 0·010$	
3	6·25	1 : 9·2	5·6	1 : 10·2	4·8	1 : 12	3·95	1 : 14·5
4	5·75	1 : 10	5·15	1 : 11·1	4·4	1 : 13	3·65	1 : 15·7
5	5·3	1 : 10·8	4·75	1 : 12	4·1	1 : 14	3·4	1 : 16·8
6	5·0°	1 : 11·5	4·5°	1 : 12·8	3·9	1 : 14·7	3·2°	1 : 17·9
7	4·7°	1 : 12·2	4·25°	1 : 13·5	3·6°	1 : 15·9	3·0°	1 : 19·1
8	4·5	1 : 12·8	4·0°	1 : 14·4	3·4	1 : 16·8	2·8°	1 : 20·5
..	..	..	..	..	..	..	..	..
10	4·1°	1 : 14	3·65	1 : 15·8	3·2	1 : 17·9	2·6°	1 : 22
..	..	..	..	..	..	..	..	..
12	3·8	1 : 15	3·42°	1 : 16·8	3·0°	1 : 19	2·4	1 : 23·9

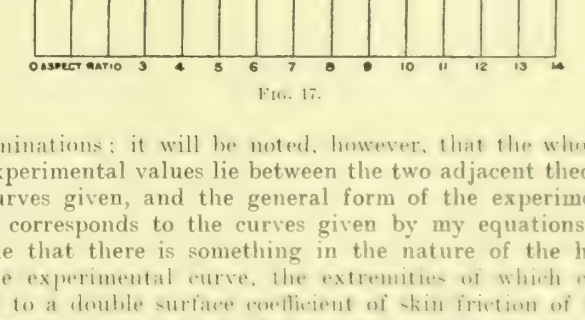


FIG. 17.

* It is an old axiom that in conducting a scientific research only one condition (when possible) should be changed at a time. In trying to adhere to this rule too literally it is easy to mistake the shadow for the substance: in the present example, to vary the length of an aerofoil of constant section may appear superficially to be "changing one condition," but in reality it is nothing of the kind.

† From "Aerial Flight," Vol. I., p. 262

‡ Report of the Advisory Committee for Aeronautics, 1911-1912, p. [illegible]

angular character of the curve may be a real feature, but I am disposed to think that is more probably due to the fact that a great deal more experimental work has been done in the region of the hump of the curve, and so more highly perfected forms have been available than for aspect ratios

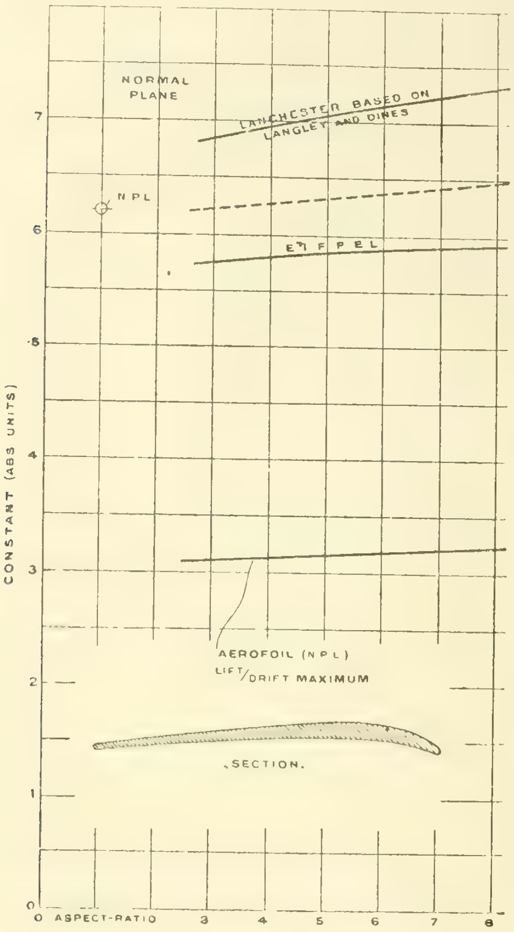


FIG. 18.

of greater or less value. It would appear probable that if equal diligence were displayed in designing and testing forms of other aspect ratios the upper theoretical curve ($\xi = 0{\cdot}015$) would be found to be very close to the truth; some confirmation of this is found in the fact that the best value for the R.A.F. 6 aerofoil, a form that had been subject to considerable study both by the Royal Aircraft Factory and the National Physical Laboratory, lies considerably above the curve representing the run of other observations.

In the National Physical Laboratory report to me on the tests of my 1894 model, it is stated that if it had been found possible to employ a velocity of 50ft.-seconds instead of 30ft.-seconds, the figure obtained would probably have reached the neighbourhood of 20. This value is also plotted as an outstanding point in Fig. 19.

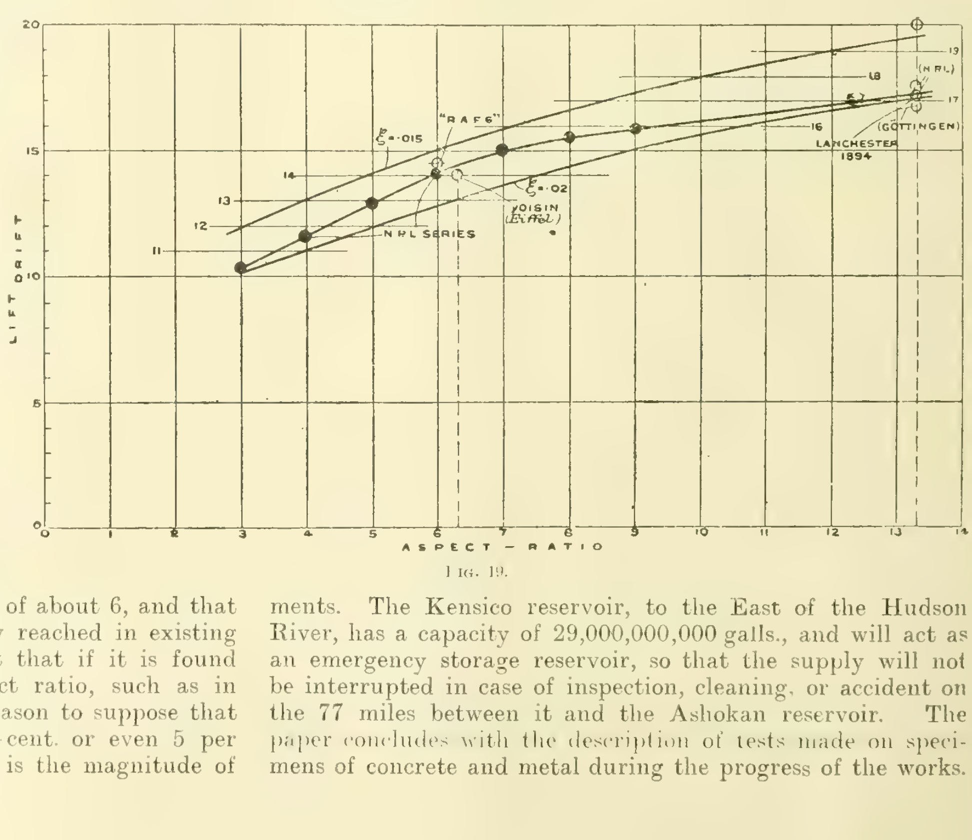


FIG. 19.

Summarising the position, it is clear that the tractive effort required to overcome flight resistance proper, viz., the aerofoil resistance, need not exceed 1 in 12 to 1 in 14, that is, 7 or 8 per cent., using an aspect ratio of about 6, and that values less than this are to-day actually reached in existing machines. It is furthermore apparent that if it is found practicable to employ really high aspect ratio, such as in my early flight models, there is every reason to suppose that a resistance coefficient as low as 6 per cent. or even 5 per cent. may prove to be attainable. This is the magnitude of the "constant gradient" of the motor-car analogy. We now pass to the consideration of body resistance.

TABLE VII.

1 Aspect Ratio	2 Type.	3 Determination by	4 Experimental	5 Calculated $\xi = 0{\cdot}02$	6 Calculated $\xi = 0{\cdot}015$
3·0	Blériot section	N.P.L.	10·1	10·2	12·0
4·0	„	„	11·5	11·1	13·0
5·0	„	„	12·9	12·0	14·0
6·0	„	„	14·0	12·8	14·8
6·0	R.A.F. 6	„	14·5		—
6·3	Voisin	Eiffel	14·0	—	—
7·0	Blériot section	N.P.L.	15·1	13·5	15·9
8·0	„	„	15·5	14·4	16·8
10·0	—		—	15·8	17·9
12·0	—		—	16·8	19·0
13·3	Author 1894	N.P.L.*	17·1	—	—
		„ *	17·6	—	—
		„ †	20·0	—	—
		Gottingen‡	16·4	—	—
		„ ‡	17·3	—	—

* Velocity, 30ft. per second.
† Value at 50ft. per second (computed by N.P.L.).
‡ Velocity not stated.

(*To be continued.*)

The Society of Engineers.—A joint meeting of the Society of Engineers (Incorporated) with the Institution of Municipal Engineers, was held on the 11th inst., when a paper was read entitled: "Notes on the Water Supply of Greater New York," by Mr. Wm. T. Taylor. The population of Greater New York, as estimated at July 1st, 1913, was 5,373,000, and in order to keep pace with its growth of approximately 135,000 persons per annum, it was long ago recognised that additions to the water supply system would be inevitable. The source eventually selected was the Catskill watershed, about 100 miles distant from New York, having an area of nearly 900 square miles. The outstanding features of the works are the Ashokan reservoir, having a capacity of 128,000,000,000 galls. and an area of 8,000 acres, and the Catskill Aqueduct, the longest and deepest in the world, with a capacity of 500,000,000 galls. a day. The Board of Water Supply consists of three Commissioners, appointed by the Mayor of New York, and assisted by a large number of technical experts and assistants, and the author describes the organisation of the engineering bureau, which is divided into five departments. The Kensico reservoir, to the East of the Hudson River, has a capacity of 29,000,000,000 galls., and will act as an emergency storage reservoir, so that the supply will not be interrupted in case of inspection, cleaning, or accident on the 77 miles between it and the Ashokan reservoir. The paper concludes with the description of tests made on specimens of concrete and metal during the progress of the works.

INDUSTRIAL AND TRADE NOTES.

South Wales Miners and the New Bill.—At a meeting of the Executive Council of the South Wales Miners' Federation, held on Monday last, the new Mines Bill, introduced by the Home Secretary, was considered. As a result of the discussion a resolution was passed protesting against the action of the Miners' Federation of Great Britain in accepting the measure, and calling upon them to withdraw their approval, and insist upon more drastic proposals for safety in collieries.

Boilermakers' Society.—The monthly report of the Boilermakers' Society gives the result of the ballot vote of the members on the adoption of the political rules under the Trade Union Act, 1913. The vote resulted as follows: For, 4,684; against, 4,316. This shows a majority of 368 in favour of the members being levied for political purposes. The total membership of the Society is over 65,000. The vote taken on the proposed working agreement with the Shipwrights' Society resulted as follows: For, 5,141; against, 956; majority for, 4,185.

Light Railway.—The Board of Trade have recently confirmed the under-mentioned Order made by the Light Railway Commissioners: Doncaster Corporation Light Railways (Extensions) Order, 1914, authorising the construction of light railways in the urban districts of Balby-with-Hexthorpe and of Bentley-with-Arksey, and in the rural district of Doncaster in the West Riding of the County of York in extension of the existing and authorised light railway undertaking of the Mayor, Aldermen, and Burgesses of the Borough of Doncaster.

Enquiry into Railway Accidents.—The President of the Board of Trade has appointed a committee to enquire into the working of the Railway Employment (Prevention of Accidents) Act, 1900, and to report what amendments, if any, are necessary. The following are the members of the Committee: Sir William Collins, M.D. (chairman), Mr. G. N. Barnes, M.P., Mr. Oliver Bury, Sir Alfred Swing, Mr. Walter Hudson, M.P., Mr. W. F. Marwood, and Sir Robert Turnbull. Mr. S. G. Spencer, of the Board of Trade, will act as secretary to the Committee.

Geared Turbine Steamer for South America.—There was launched on the 12th inst., from the yard of Messrs. Cammell, Laird, & Co., Birkenhead, the twin-screw steamer "Cuidad De Buenos Aires," the first of two vessels building for the Argentine Navigation Company. The vessel is intended for cross-channel service between Buenos Aires and Monte Video. The propelling machinery consists of two sets of Parsons' compound geared turbines. It is noteworthy that this will be the first geared turbine steamer built for South American waters.

Engineers and New National Agreement.—The Executive Council of the Amalgamated Society of Engineers have decided to ballot their members on a proposal to substitute a new national agreement with the Engineering Employers' Federation for the old agreement and premium bonus memorandum, which, by reason of the men's notice, expired in March. The men are recommended to give the necessary powers to their executive to negotiate a new agreement, and in the meantime a provisional agreement has been adopted for the purpose of avoiding any stoppage of work either of a partial or general character.

Mining Legislation.—The Home Secretary, in a written reply to the Chancellor of the Exchequer, says he does not anticipate that the Government will be able this session to introduce any legislation in regard to the mining industry beyond the Bill which is now before the House. He points out that the question of the prevention of coal dust explosions and other points which have been raised by the reports on the Senghenydd and other recent disasters, can be dealt with by regulations under the Act without legislation, and he hopes as soon as the enquiries now in hand are completed to propose regulations dealing with the matters in question.

The Durability of Dermatine Hose.—A striking testimonial of the durability of Dermatine Hose has been received by the Dermatine Company, Ltd., Neate Street, Camberwell, London, S.E., from Mr. W. Ryder Richardson, the well-known secretary of the Royal St. George's Golf Club, Sandwich, Kent, where the Amateur Golf Championship commenced on the 18th inst. He states that "After various trials I have not found any hose that stands such hard wear as the Dermatine Hose. If this weather continues, we shall be using the hose day and night, especially just now, prior to the amateur championship, when we want the greens in extra good order."

Employment in the Engineering Trades.—According to the Labour Department of the Board of Trade, employment in April continued good on the whole, and showed little general change from the previous month. The coal mining, engineering, and shipbuilding trades were still well employed, but there was some decline in pig iron and steel and tinplate manufacture. Compared with a year ago employment showed a decline which was especially marked in the pig iron and steel and engineering trades. The changes in rates of wages which came into operation in April affected 220,000 workpeople, of whom 16,000 received an increase of £3,300 per week, and 204,000 sustained a decrease of £12,000 per week, the net result being a decrease of £8,700 per week.

Shropshire Railway Development.—In the annual report of the Shropshire and Montgomeryshire Light Railway Company reference is made to a proposed railway development in Shropshire. The present railway controlled by the company was reopened some two years ago after having lain derelict for over 30 years. Formerly it was known as the Old Potteries Railway, and the original intention of the promoters was to run through from the Cambrian system to the Potteries, but the railway never got beyond Shrewsbury. The report of the directors states that steps are being taken to revive what is known as the Market Drayton extension scheme, which has been dormant for some years. At Market Drayton it will link up with the North Staffordshire system.

New Oil-carrying Steamer.—The Greenock and Grangemouth Dockyard Company launched from their Greenock yard on the 14th inst., the oil-carrying steamer "Saxonian," built to the order of the Petroleum Steamship Company, London. The dimensions of the vessel are: Length, 376ft.; breadth, 51ft. 9in.; carrying capacity, 7,000 tons on 23ft. 10in. draught. The vessel has 28 oil-tight compartments for the carriage of all kinds of oil in bulk, from benzine down to the heaviest grades. The pump rooms contain powerful sets of pumps capable of pumping from either side of the ship and of discharging ashore from either side or over the stern. They are also capable of pumping from one tank into another and discharging at the same time. Triple-expansion engines will be supplied by Messrs. Dunsmuir & Jackson, Govan.

Accidents as Related to the Time of the Week.—The question of the influence of the day of the week on the numbers of accidents was touched on recently in an address by Dr. Harold H. Baker, medical superintendent of the Bausch and Lomb Optical Company, Rochester, N.Y., at a meeting of the Efficiency Society of Rochester. Figures, covering 1,300 accidents, showed that Mondays and Saturdays were productive of a much higher percentage of accidents than other days of the week. The daily number of accidents, on an average, were found to be as follows: Monday, 253; Tuesday, 196; Wednesday, 194; Thursday, 197; Friday, 195; Saturday, 265. This was explained thus: On Mondays the workmen are not properly keyed up to their tasks; there may have been dissipation over Sunday. In other words, their minds are not alert. On Saturdays the same conditions exist, except that the men are rushing their work, or their minds are on plans for the rest-day.

Proposed British University for China.—An appeal has been made in the form of a memorial addressed to the Chancellor of the Exchequer and to the Secretary of State for Foreign Affairs asking that out of the annual payments made by China on account of the Boxer indemnity a grant of not less than £300,000 shall be made towards the establishment of a British University at Hankow, or such other influential centre in China as may be considered most suitable. It is pointed out in the appeal that the industrial and commercial interests of this country with China far exceeds those of any other nation, and that the development of China's resources depends upon the higher education of her students. In order to influence the character and sympathies of Chinese students, it is proposed to establish a University under British auspices. The Association of Chambers of Commerce points out that America has already realised the necessity of assisting the Chinese through education, and Germany has also used Government funds to establish colleges in the north of China.

Annual Conference of British Foundrymen's Association.—The eleventh annual conference of the British Foundrymen's Association was held last week, in the Technical School, at Leicester, Mr. Sydney A. Gimson presiding. The report of the council for the year 1913 was presented and showed that the membership was now 974 as against 923 in the previous year. The accounts show that the total revenue for the year was £470, and the expenses £400, leaving a balance on the year's working of £70, which, added to the surplus from the previous year, shows a total credit balance of £187. A number of interesting papers were read and discussed at the meeting, including one on "Annealed Castings," by Mr. R. Buchanan; a second on "Cores," by Mr. F. C. Pulsford; a third on "Design and Working of the Foundry Cupola," by Mr. E. L. Rhead; a fourth on "Foundry Yields," by Dr. Percy Longmuir and Mr. W. H. Robinson; and a fifth on "The Production of Plaster of Paris Patterns," by Mr. C. Heggie. It is our intention to reproduce several of these papers in early issues.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1913.

Machines for manufacturing metal tubes. Meakin & Meakin. 2166.
Method of injecting liquid fuel into internal-combustion engines. Evans. 7297.
Process for refining copper or other metals. Rockey & Eldridge. 7409.
Radial cylinder internal-combustion engines. Adams. 7453.
Valves and valve gear for internal-combustion engines. Lilwall and Searle. 9446.
Water-tube boilers. Vulcan-Werke Hamburg und Stettin Akt.-Ges. 9670.
Apparatus for the catalytic combustion of gaseous or vaporous combustibles. Schmidt & Krieger. 9678.
Appliances for spraying or atomising liquids by air or gases. Samuelson & Backhouse. 9823.
Automatic disengaging device for belt pulleys. Hansen. 9965.
Carbonisation of coal. Lewes. 9988.
Exhaust arrangements of steam engines. Eastwood, Becker, and Newton, Bean, & Mitchell. 10011.
Carburetters for internal-combustion engines. Gits. 10059.
Automatic starting devices for internal-combustion engines. Robertson. 10070.
Power hammers. Hamilton. 10145.
Steam separator. Brown. 10386.
Percussive rock drills. Wakfer & Peck. 10566.
Starting of internal-combustion engines. Leitner. 10656.
Starting gear of internal-combustion engines. Vickers, Ltd., and Bourcier. 10677.
Carburetters for internal combustion engines. Dewis & Zillwood. 10697.
Pipe tongs or wrenches. Smither. 10899.
Revolving-cylinder engines. Proux & Guinot. 10908.
Regenerative furnaces. Walsh & Priestley. 10950.
Construction of ships. Welch. 11404.
Internal-combustion engines. Paterson. 12455.
Apparatus used in the manufacture of tin plates. Thomas, Thomas, & Davies. 12601.
Apparatus for riveting stay bolts. Pullen. 12621.
Firebars for boiler furnaces. Butterworth. 13484.
Internal combustion engines. Lea. 13966.
Reversing gear for fluid-pressure engines. Martin, and Douglas and Grant, Ltd. 14450.
Process for manufacturing steel plates, armour plates, and hollow bodies. Braun. 15376.
Manufacture of seamless tubes. Diescher. 16120.
Rotary distributing valve mechanism for multi-cylinder internal-combustion engines. Schaar. 18495.
Cranes for stripping and handling ingots and moulds. Crowe. 18607.
Pistons of internal combustion engines. Vickers, Ltd., and Bourcier. 19185.
Stop valves. Foster. 19368.
Dressing of tin ores. Martin. 19514.
Apparatus for automatically regulating feed-water supply to boilers. McCallum. 19725.
Valves for internal-combustion engines. Ernst. 21530.
Speed indicator. Meier Mandli. 21667.
Regenerators for furnaces. Niewerth. 21739.
Locomotive cylinders. Adamson. 22883.
Valves for internal-combustion engines. Wright & Whaley. 24563.
Ball bearings. Soderlund. 25138.
Means for controlling cushioning in steam engines. Scheil. 25300.
Spray carburetters for internal-combustion engines. West. 25641.
Drop-hammers. Brett & Brett. 25878.
Flux for aluminium and its alloys. Gelly. 26026.
Screws, bolts, and nuts. Hempel. 26071.
Process of manufacturing acid resisting pipes and vessels. Strzoda. 26732.
Valves of internal combustion engines. Burn. 26892.
Ball bearings. Markische Maschinenbauanstalt "Teutonia" Ges. 27626.
Boring machines. Dixon. 27671.
Composition for application to iron for the purpose of acting as a preservative. Aglionby & Howkins. 27698.
Variable and reversing friction driving gear for motor cars. G. W. K., Ltd., and Wood. 27721.
Means for admitting air or fuel to internal combustion engines. Brettell. 30057.

1914.

Valve apparatus for percussive rock drills. Rayner. 617.
Means for starting internal combustion engines. Giorgi. 1771.
Bearings for rope pulleys. Rowney. 2012.
Rope railways. Thunhart. 2186.

ELECTRICAL, 1912.

Excilation of dynamos. Rolfe. 24898.

1913.

Production of electric contacts. Scott & Deats. 2169.
Selecting devices for telephone systems. Katz. 2302.
Charging of accumulators from a variable speed dynamo. Thomas, and Thomas Transmission, Ltd. 7252.
Method of heating substances by electricity. Broadbent and Davies. 9105.
Resistance for regulating the current in an electric circuit. Mansell. 9447.
Variable resistances for automatic regulation of electric currents. Bloxam. 9959.
Means for raising and supporting arc lamps. Hughes. 10188.
Electric soldering irons. Railing & Krause. 10500.
Device for the automatic maintenance of phase equality of the currents of parallel connected alternating-current machines. Allgemeine Elektricitäts Ges. 10609.
Control of alternating current commutator electric motors. Siemens-Schuckertwerke Ges. 11313.
Electrical relays. Baker & McKechnie. 11751.
Apparatus for charging electric accumulators. Leitner. 12639.
Metal vapour arc lamps. Deutsche Gesguhlicht Akt.-Ges. 15046.
Method of and means for determining the electrical characteristics of high-frequency oscillation circuits. Carden. 15283.
Electric switches mechanically controlled from a distance. Hodgson. 15642.
Mounting of electromotors on tramway vehicles. Delmez. 17005.
Distribution systems for vapour electric devices. British Thomson-Houston Company. 19022.
Magneto-electric ignition apparatus. Hill. 21509.
Replacement fuses applicable also for use as electric switches. Donovan. 23035.
Electrical resistance thermometers. Mellersh-Jackson. 23720.
Oil transformers. Weiss. 24162.
Magnetic separators. Fried. Krupp. Akt. Ges. Grusonwerk. 24355.
Connection plugs for electric circuits. Chapman & Kenney. 25675.
Rectifier for alternating polyphase currents. Siemens Bros. Dynamo Works, Ltd. 29763.

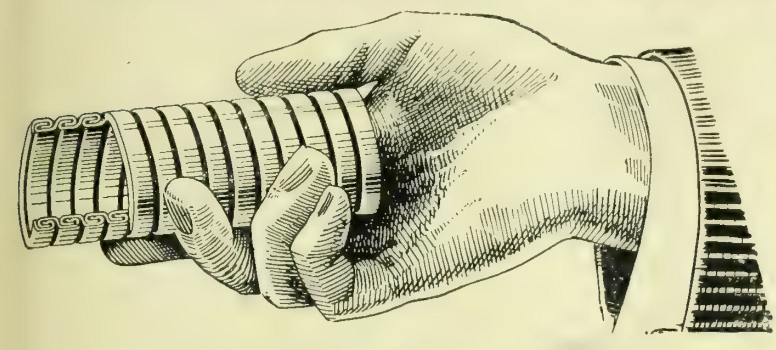
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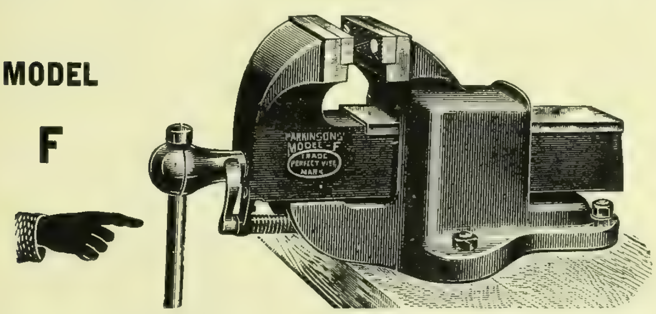
Electric incandescent lamps. Loewenstein. 2843.
Telegraphy. Judd, Davies, and Eastern Telegraph Company. 5037 and 5831.
Interrupters for electric circuits. Pollak. 5070.

METAL QUOTATIONS.

TUESDAY, MAY 19TH.

Aluminium ingot	86/– per cwt.
,, wire, according to sizes, &c. ......from	107/4 ,,
,, sheets ,, ,, ... ,,	112/– ,,
Antimony	£27/–/– to £28/10/– per ton.
Brass, rolled	$7\frac{1}{8}$d. per lb.
,, tubes (brazed)	$9\frac{5}{8}$d. ,,
,, ,, (solid drawn)	$7\frac{7}{8}$d. ,,
,, ,, wire	$7\frac{1}{8}$d. ,,
Copper, Standard	£63/5/– per ton.
Iron, Cleveland	$51/4\frac{1}{2}$,,
,, Scotch	$57/4\frac{1}{2}$,,
Lead, English	£19/5/– ,,
,, Foreign (soft)	£18/17/6 ,,
Mica (in original cases), small	6d. to 3/– per lb.
,, ,, ,, medium	3/6 to 6/– ,,
,, ,, ,, large	7/6 to 11/– ,,
Quicksilver	£7/–/– per bottle.
Silver	$26\frac{5}{8}$d. per oz.
Spelter	£21/7/6 per ton.
Tin, block	£151/–/– per ton.
Tin plates, I.C.	12/6 per box.
Zinc sheets (Silesian)	£24/10/– per ton.
,, (Stettin; Vieille Montagne)	£24/12/6 ,,







The Mechanical Engineer.
An Illustrated Weekly Journal
Vol. 33, No. 853

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Telegrams: "Scientific," Manchester.
Telephone No. 6055 City.

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Domestic Smoke.

WE are glad to note that a more reasonable sense of proportion appears at last to pervade the minds of the smoke prevention enthusiasts when discussing the problems associated with their laudable efforts to improve the atmosphere of manufacturing towns. A clear perception of the extent to which the domestic chimney contributes to the nuisance is certainly an important step towards finding a remedy. It is useless to rail against manufacturers alone as if they were the only sinners, when it can be shown that householders, in the aggregate, are responsible in large towns for from 40 to 60 per cent. of the smoke nuisance, the percentage, of course, varying with the town and character of the local industries. Attention has for a long time been concentrated on boiler furnaces and chimneys, and as we have often pointed out, there is little room for improvement in the efficiency of furnace apparatus, and the factory owner undoubtedly possesses little immunity from prosecution for any lapse in respect to their working. On the other hand, the householder can do pretty much as he likes. It is well to recognise the facts in considering any remedy. At the second meeting of the Committee on Smoke Abatement, Prof. Graham, the president of the Smoke Abatement League, said that nearly half the smoke found in the centre of a city like Manchester was domestic. This, it was admitted, was a fair average, as also that the total consumption of coal for domestic purposes was only about one-fifth. If Manchester is taken as a basis, it will be obvious that if one-fifth of the coal produces half the smoke the domestic grate is by far the worst offender. In Glasgow is has been estimated that as a smoke producer one factory chimney was equal to 39 domestic chimneys. It is not easy to make correct comparisons, but if these figures (which are given by the Smoke Abatement League) be accepted and applied to London, with

the assumption that there are three smoking chimneys to every two houses, it can be shown that more than one-half of the smoke pall is derived from private dwellings. Different equivalents for purposes of comparison would give greater or lesser results, but these suffice to show how serious is the proportion which domestic smoke bears to the whole, and the problem is how to prevent it. So far as we know there are only four ways of dealing with the problem, viz., central heating by a public service of steam or hot water, electrical heating, the use of smokeless fuel in open grates, or gas fires. The first of these methods is somewhat extensively adopted in America for private dwellings, and in this country is a common method of dealing with the heating of large institutions, though we are not aware that it has been adopted by any local authority as a public service, like the distribution of gas, water, or electricity. The latter is now used on a small scale for heating purposes in many ways, but these are mainly for special manufacturing processes, and though electrical radiators and cooking apparatus of a variety of forms are now on the market, the cost of current must inevitably prohibit its general use for the heating of rooms. A more practical method of doing this would be the general adoption of a comparatively smokeless fuel, such as may be obtained by the partial carbonisation of coal, by which the more volatile smoke-forming products are driven off and yet sufficient left to give a flaming, smokeless species of coal; but this is only feasible on a large scale, and though some experiments in this direction have been made they have not, so far as we are aware, been a commercial success. It does not, however, follow that they might not be, by better organisation and possibly the exercise of compulsory powers as to its use. One advantage of this solution is that it would require no change in domestic arrangements, and would not interfere with the general predilection for the bright, open fire. It might be that such fuel is a trifle more expensive, but if it were generally adopted there ought not to be much room for complaint on this score. The remaining alternative is the gas fire. This is now largely adopted for cooking purposes, and to a lesser extent for warming rooms; but the cost of gas in nearly all large towns is at present so high as to make it prohibitive of general application in this direction. There is no doubt that the cost could in a great many cases be greatly reduced to the consumer were the gas department in municipal undertakings not so often regarded as a profit-making business for reducing rates. But apart from the question of expense, there is a good deal of prejudice against the gas fire, and it cannot all be dismissed as baseless. Under some conditions they work efficiently, but under others they can be, and often are, a nuisance, and it would help to dispel prejudice if the reasons for this difference of behaviour were better realised. The primary advantage claimed for the gas stove against the open coal fire is that the major portion of the heat in the former is utilised for warming the room, whereas in the latter it goes up the chimney. This is no doubt true, and it is equally so that the temperature may be better regulated; but this control may easily cause trouble. It must not be forgotten that the products of combustion from a gas fire, though not so visible, are quite as deleterious as those from an ordinary coal fire, and it is quite as imperative that they should escape from the chimney top and not into the room. With a coal fire there is seldom any difficulty about this except with badly-designed chimneys on gusty days, owing to the high temperature of the gases in the chimney and the strong current induced. The price paid for this is doubtless in most cases an extravagant expenditure of heat, but it has the virtue of efficiency. In gas stoves which possess the merits of efficiency as far as heat utilisation is concerned, the current of air passing into the chimney is small in quantity and low in temperature. To begin with, this means that the ventilation of the room is less effective, and, secondly, that the temperature in the chimney being less pronounced the upward current is feeble, and in some cases where the chimney is high it is difficult to create sufficient draught, or if this exists it is easy for a down draught to be set up in the room containing the stove by weather conditions or in other rooms by the influence of other fires, the opening of doors, &c. In such cases it is easy to understand the gas stove may become a serious nuisance. The danger of this is increased the greater the efforts made to secure a high efficiency. It should not be forgotten that whether gaseous fuel or solid fuel be burnt in dwellings, the efficiency of the chimney depends entirely on the temperature maintained in it. This is the price that must in any case be paid for ventilation unless it is effected by mechanical means, such as a fan, and in private dwellings this, of course, is out of the question. When comparisons are made between gas stoves and coal fires, the question of chimney efficiency is often ignored, and, though it may be possible to give a large proportion of the heat into a room with adequate ventilation under favourable conditions, the gas stove in practice has to meet wide variations both as regards the weather and draught-disturbing influences inside the building. To do this effectively a higher chimney temperature is necessary than gas advocates usually think, and of course this means a correspondingly increased consumption of gas. If this is not provided, there is always a risk of trouble and of the gas stove being condemned as a nuisance.

Launch of H.M.S. "Galatea."—Messrs. William Beardmore and Co., Naval Construction Works, Dalmuir, launched on the 14th inst. the light armoured cruiser "Galatea" of the "Aurora" class. The vessel is one of eight sister ships laid down under the naval programme of 1912-13. She is 410ft. in length, 39ft. in breadth, of about 3,500 tons displacement, and is expected to develop a speed of 30 knots. Her propelling machinery will develop 30,000 h.p., and will consist of four independent turbines, each driving its own propeller, and arranged in two separate watertight compartments, so that each pair of turbines will form a complete and independent propelling installation. There will be an astern turbine incorporated with each of the ahead turbines in the same casing, so that all four propellers will be available for going astern — a very important feature for manœuvring purposes. Steam will be supplied by eight water-tube Yarrow boilers, arranged in two watertight compartments, and adapted for burning oil fuel only.

Manchester Association of Engineers.—On Thursday, the 14th inst., upwards of 100 members of the above association had the privilege of viewing the extensive motor-car works of Messrs. Rolls-Royce, Ltd., Derby. The party, which included the president, Mr. Edward G. Hiller, the chief engineer of the National Boiler and General Insurance Company, Ltd., were received at the works by Mr. A. Wormald, the works manager, and the secretary, Mr. De Looze, who, with the assistance of other members of the staff, conducted the visitors through the works. The party were greatly impressed with the extent of the works, the various systems of working, and especially with the experimental department, and the unique methods of testing every detail of the motor-car before its issue from the works. On the termination of the inspection the party adjourned to the Midland Hotel, where, after tea, a cordial vote of thanks was passed to the firm for the privilege afforded.

THE NATURE OF FATIGUE STRESSES.

A PAPER by Mr. C. E. Stromeyer, the Chief Engineer of the Manchester Steam Users' Association for the Prevention of Boiler Explosions, recently read before the Royal Society, revives a subject which was first mooted in 1867 by Wöhler, who explained the frequent failures of railway axles and similar objects by showing experimentally that steel and iron can be broken at comparatively low stresses if these are repeated a sufficient number of times, their number exceeding in some cases 40 millions. No general law seems to have been drawn from these tests or from those by Sir Benjamin Baker, but two years ago Mr. Stromeyer, in discussions on papers which were read before the Institution of Civil Engineers, and before the Institution of Mechanical Engineers, mentioned experiments of his own which revealed a definite fatigue law and which pointed to the probability of the existence of a definite fatigue limit for every material, *i.e.*, a limiting stress which if repeated an infinite number of times will result in fracture. A knowledge of the exact value of this limit will, of course, be of great advantage to engineers, for it should enable them, as was recently done by Mr. Stromeyer at a meeting of the Institute of Naval Architects, to utilise the ever-accumulating experiences of actual failures for the determination of certain as yet unknown stresses. Thus one copper steam pipe which had failed on a steamer after being vibrated by the engines for 10 years, or, say, 150 million times, had, according to his formula, been subjected during that period to alternating stresses of about 5·27 tons per square inch. Whereas another copper pipe which failed after only 4 hours running during a heavy gale must, according to his formula, have been subjected to alternating stresses of over 13 tons per square inch. When information about the fatigue-resisting properties of steel are available, similar estimates can be made for the as yet unknown alternating stresses which have brought about failures of railway axles due to the long-continued vibrations.

Mr. Stromeyer's paper deals exclusively with the question of endurance or fatigue qualities of metals. The apparently incongruous results obtained by previous experimenters, including those by Wöhler, made it appear probable that samples taken from different parts of a bar or plate might differ so much in quality that the law of fatigue would be masked by local variation of quality. The test pieces of the present first series (bending) were therefore shaped in such a manner that consecutive pieces were separated from each other in the original plate by only 1in. The test results were found to be very consistent, and could be expressed by the formula

$$S_n = Fl + C(10^6 : N)^1,$$

where S_n is the nominal alternating stress which will cause fracture after N repetitions, Fl is the fatigue limit found by extrapolation from a series of tests resulting in fracture, and C is a constant. A comparison was made of previous tests with the help of this formula, and it was found to agree well with those of Wöhler, Baker and Eden, Rose and Cunningham.

The torsion fatigue tests were made with the same materials as used in the above tests, and the results also agreed very closely with the above formula, except that new values for Fl and C were found. A comparison was made between the fatigue limits as found by the bending-fatigue tests and by the torsion-fatigue tests, the ratio between the two averaging about 3 to 2. The comparison between the bending and shearing stresses, which will produce fracture after a certain number of revolutions, has also been made, but is of relatively less value, for these stresses are merely nominal ones and the formulæ which would reduce them to actual stresses are not the same for bending as for torsion.

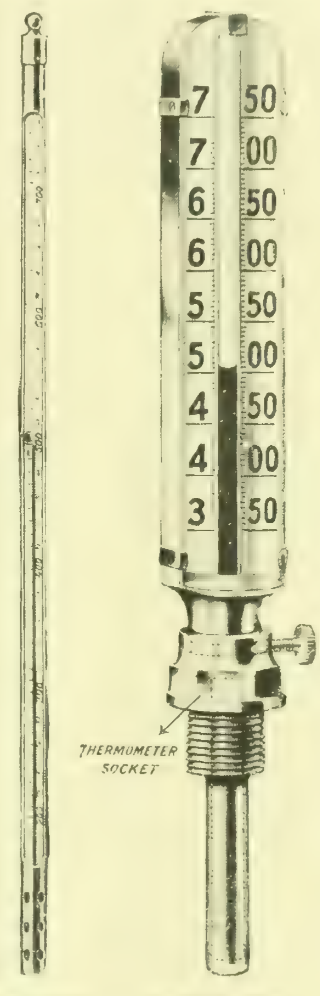
The enquiry was extended to the measuring of the heat generated during fatigue tests. It was found that with low alternating stresses no heat was produced, or, at any rate, so little that it could not be measured, but when certain limiting stresses were exceeded then the generation of heat was quite perceptible. The stresses, at which there was a first indication of heat production, were assumed to be the fatigue limits of the material, for the heat production suggests internal friction and these limits agreed reasonably well with the fatigue limit (Fl) which were found by extrapolation with the help of the formula given.

This calorimetrically determined fatigue limit was practically a fixed value for any one quality of material, the most interesting case being a crank shaft from which 19 samples were cut. In the first group of three samples cut from the end of the shaft, the minimum and maximum values of the fatigue limit were 11·15 and 11·40 tons per square inch. In the second group of eight samples cut from between the crank webs, the fatigue limits ranged from 11·30 to 11·[illegible] tons per square inch, and in the third group of eight samples they ranged from 12·05 to 12·15.

These results agree amongst themselves far better than the tensile tests of the same material, tests which at present are looked upon as reliable indicators of quality.

MAGNIFYING THERMOMETERS.

IN electricity works, breweries, gasworks, sugar factories, chemical works, heating plants, baths, &c., it is frequently the case that thermometers are fixed in inaccessible positions, with the result that the temperatures are not checked as regularly as should be the case, due to the inaccessibility of the instruments. To meet this difficulty Messrs. T. Sugden, Ltd., of 180, Fleet Street, London, E.C., are supplying thermometers which enable the temperatures to be read with ease from a considerable distance, due to the scale and mercury column being magnified. The illustration shows a comparison between one of the many types of magnifying thermometers supplied by this firm, and the ordinary thermometer frequently adopted. The placing of a lamp (electrical, gas, or any other illuminant) behind the scale facilitates still further the reading, but the daylight falling upon the back of the scale is found, as a rule, ample to make the reading easy. In addition to the advantage of magnification, it may be added that the thermometers are of accurate and robust construction. The instruments are supplied in a variety of types to suit all kinds of positions, and with ranges of scales up to 1,000° Fah.



Usual pattern. Magnifying type.

COMPARATIVE ILLUSTRATIONS OF AN ORDINARY THERMOMETER AND A SUGDEN'S MAGNIFYING THERMOMETER.

Service Tests of Bronze Railway Journal Bearings.—Tests have recently been conducted by the American Metal Company, Pittsburg, with solid bronze castings made without babbitt surface; the material being composed of 65 per cent. copper, 30 per cent. lead, and 5 per cent. tin. A 22lb. bearing was placed under the tender of Baltimore and Ohio locomotive No. 2,127 (Pacific type). It was examined after [illegible] miles run and found worn down $\frac{1}{32}$in.; the other tender bearings were each rebabbitted six times. This bronze, it is claimed, can be hardened for mill brasses; tests of such bearings were made by placing two 75lb. brasses under the rolling table of an 108in. plate mill in the Soho plant of Jones & Laughlin, Pittsburg. They gave continuous service for four weeks which is claimed to be twice as long as phosphor bronze bearings used. These parts cannot be lubricated on account of position.

INTERNAL STRAINS IN COLD-WROUGHT METALS, AND SOME TROUBLES CAUSED THEREBY.*

BY PROF. E. HEYN.†

In the first place I desire to express my thanks for the privilege your Council has conferred upon me by inviting me to deliver the May lecture before this Institute. I avail myself of the opportunity to direct your attention to some work which has been carried out in recent years in the Königl. Materialprüfungsamt, Gr. Lichterfelde, by my friend Prof. Bauer and myself, with a view to clearing up some peculiar effects in the behaviour of cold-wrought metals which came to our knowledge, and which caused much trouble to the practical engineer.

The phenomena with which I am about to deal come under the heading of "internal strains." If portions of a solid, or of a number of solids forming together one rigid mass, are hindered from assuming the natural length which they would assume in the absence of any load or hindrance, this solid or number of solids is said to be under strain. The strained condition may be brought about (1) by forces acting on the solid from outside (external forces); but strains may also exist in the solid (2) without any observable action from outside, or after the external action has ceased. These latter strains I define as "internal strains"; the solid is, so to say, "self-strained."

For instance, all structural members secured together by bolts or rivets are self-strained, since the bolts, nuts, or rivets,

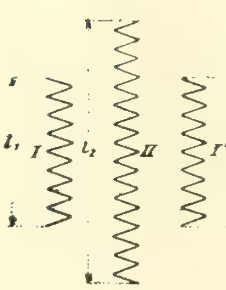


FIG. 1.

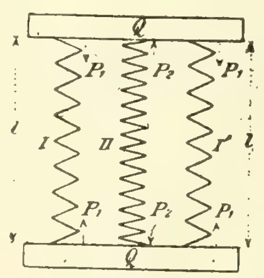


FIG. 2.

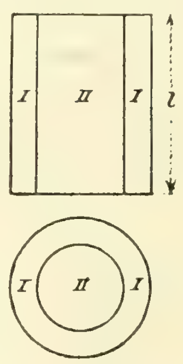


FIG. 3.

as well as the surfaces on which they press, are elastically deformed. The same holds true for structural members which have been coupled together by the process of shrinking on. In all these cases internal strains have been intentionally produced in the structural members, and it is possible to estimate the approximate amount of these strains; besides, in designing, provision may be made for partly balancing the internal strains by the external ones set up by the action of external loads during service, thus increasing the resisting power of the member.

On the other hand, if self-straining is set up in structural members unintentionally and without being provided for, and if it so happens that the internal strains are added to the strains caused by the external load which the member is designed to bear in service, failure may be caused suddenly or after repeated loading and unloading. It may even happen that the uncontrollable internal strains in the structural member come so close to the tensile limit of the material, that additional strains of a very trifling amount may suffice to give rise to fracture. I need only refer to the explosion of castings affected by severe self-straining due to unequal cooling, to the sudden failure of boiler ends which have been dished or treated in an unsuitable manner, and so on. Seen from this point of view, internal strains appear as a source of serious danger, or at least of serious troubles.

In order to illustrate more clearly the nature of internal strains, I refer to Figs. 1 and 2. The first of these shows three unloaded helical springs, I, I′, and II, with the respective lengths l_1 (for springs I and I′) and l_2 (spring II). On connecting these springs by two crossheads, Q, as shown in Fig. 2, they are forced to assume the common length l, which exceeds l_1 and is less than l_2. Hence the springs I and I′ grow in length elastically, giving rise to internal strain in tension, whereas spring II is compressed elastically, and is thus subjected to internal compression strain. The model illustrated by Fig. 2 is typical of a self-strained system. The two springs I and I′ tend to bring the two crossheads QQ nearer to each other with a force P_1, the spring II, on the other hand, tends to increase the distance between Q and Q with a force P_2. In order that equilibrium may be established, we must have $P_1 + P_1 - P_2 = 0$.

By closely considering Fig. 2 a method can be found for distinguishing a system under internal strains from an unstrained one.

(*a*) If in the model illustrated in Fig. 2 (model of a self-strained solid) the two springs I and I′ are cut through, the

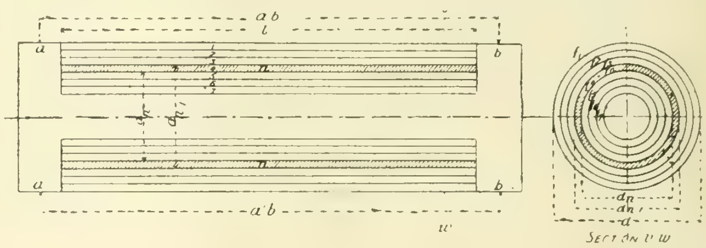


FIG. 4.

initial distance l of the two crossheads Q will instantly *increase* to the amount $l_2 > l$.

(*b*) If things be reversed in Fig. 2, that is to say, if the unloaded springs I and I′ be of equal length l_1, which is in excess of the length l_2 of the unloaded spring II, a new self-strained system will exist with the springs I and I′ under compression and spring II under tension. On cutting through the springs I and I′ the distance l of the two crossheads Q will *decrease*, attaining the value l_2 less than l.

(*c*) We have to consider a third case, in which the three unloaded springs I, I′ and II are of equal length l. After combining them in the manner shown in Fig. 2 by two crossheads, a model free from internal strains is obtained. On cutting through the two springs I and I′ *no change* of the distance l of the crossheads will ensue.

The deductions made under (*a*) to (*c*) may be applied to the case of a rod of circular section, as illustrated in Fig. 3. If the rod is free from internal strains the length l of the portion II must remain unchanged after the outer layer I is turned off on a lathe. This would correspond to the case (*c*). It is obvious that the measuring and re-measuring of the length before and after turning must be carried out at identical temperatures. Since in turning heat is generated, sufficient time must be left after turning for the piece II to assume the same temperature as before.

If, however, after taking away the layer I the remaining portion II of the rod increases in length, the existence of case (*a*) is established. Then, in the original bar, the portion I was under tension, the portion II under compression strains.

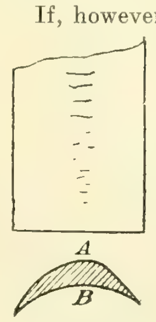


FIG. 5.

If, finally, after turning off the layer I, the portion II is shortened, this corresponds to case (*b*); that is to say, in the original bar the layer I was under compression and the core II under tension.

These considerations give the key to a method, which has been devised in the Königl. Materialprüfungsamt, for ascertaining whether a bar or some other structural member is self-strained or not, and also for obtaining an idea of the order of magnitude of the internal strains. The method is illustrated in Fig. 4 as it is used for determining the internal strains, which may be present in a round bar in the direction of its axis. The distances $a\,b$ and $a'b'$ of marks made on two opposite generating lines of the cylindrical surface of the bar are measured by the aid of a comparator. Over a definite length l between the marks thin layers f'_1, f'_2, f'_3 . . . are turned off successively. After each layer is removed, the distances $a\,b$ and $a'b'$ are remeasured. If these remain unchanged, the bar was free from longitudinal internal

* May lecture delivered before the Institute of Metals, May 12th, 1914.

† Royal Technical Institute, Charlottenburg, and Director of the Royal Prussian Institute for Testing Materials, Berlin—Lichterfelde.

strains. If, however, they change, the bar had been subjected to internal strains, and conclusions may be drawn as to their magnitude in the following way:—

Let λ_1 be the average change in the distances $a\ b$ and $a'b'$ respectively after turning off the first layer f'_1, λ_2 the change of these distances after the second layer f'_2 is removed, and so on, and finally, λ_n the corresponding change after the removal of the layer f'_n, let E be the modulus of elasticity of the material of the bar, f'_n the sectional area of the nth layer taken off $(f'_n = \frac{\pi}{4}(d^2_{n-1} - d^2_n))$, f''_n and f''_{n-1} the sectional areas of the remaining portion of the bar after turning off the nth and the $(n-1)^{th}$ layer respectively.

$$(f''_n = \frac{\pi}{4} d^2_n;\ f''_{n-1} = \frac{\pi}{4} d^2_{n-1}).$$

On the assumption that Hook's law holds good, the equation is obtained:—

$$\sigma_n = \frac{E}{l} \cdot \frac{f''_n \lambda_n - f''_{n-1} \lambda_{n-1}}{f'_n},$$

where σ_n is the internal stress, which initially prevailed in the n_{th} layer of the bar, before turning took place. A positive value of σ_n refers to *tension stress*, a negative one to compression stress.

Internal strains can be set up in solids by various causes.

(*a*) *By unequal cooling or heating.* α. As an example, consider the exterior layer I of the bar in Fig. 3 being heated to a higher temperature than the central core II; then portion I will tend to expand more than II. The two portions I and II being rigidly coupled together must attain one common length; this can only be attained by stretching the core II and by compressing the outer layer I. The consequence will be internal strains, viz., compression in I and extension in II.

β. If the bar, initially free from self-straining, be cooled from some definite temperature unequally, so that at a definite time the layer I is cooler than the core II, internal strains must be produced, viz., tension in I and compression in II.

If in the cases α and β the internal strains do not exceed at any time the elastic range of the material, they can exist only temporarily, as long as the difference in temperature between the different portions of the bar is maintained, and must disappear after equalising the temperature. If, however, the strains brought about in the cases α and β exceed the elastic range, internal strains remain after cooling and equalising to atmospheric temperature, as, for instance, in castings, forgings, and so on.

(*b*) *By swelling.* Let us suppose the bar in Fig. 3 to be made of a material such as wood, which absorbs moisture from the air, giving rise to a change of volume and length. Self-straining may then be brought about, if the different layers absorb different amounts of moisture.

(*c*) *By transformation.* If the bar (Fig. 3) is supposed to consist of a material which, within a definite range of temperature, undergoes a transformation accompanied by a change of volume, and if the transformation in the portions I and II does not go on at the same time, self-straining may set in, as, for instance, in the case of swelling or disintegrating cement clinker.

Summarising, we may say that self-straining must be produced in all cases where portions of a solid or of a set of rigidly connected solids by any cause whatever are given a tendency to assume different lengths, and when by cohesive forces they are hindered from following this tendency and are forced to adapt themselves to a common length by *elastic* deformation. The latter is an essential feature. If we could imagine a perfectly plastic solid incapable of undergoing elastic deformation, the differences in length induced in various portions of its mass by any cause would be equalised by plastic yielding, leaving the solid free from internal strains. If the plastic yielding reached a degree exceeding the cohesive limit, partial or total fracture would be brought about.

Most of the materials used by the engineer are far from fulfilling the condition of such perfect plasticity, and cannot undergo deformation without concomitant elastic deformation. Thus, when they are subjected to deformation above their elastic range, and when these deformations are of a different degree in different portions of their mass coupled together by cohesive forces, differences in length must arise between neighbouring portions, which can only partly be equalised by plastic yielding, leaving a remainder to be equalised by elastic deformation, so that internal strains must be the unavoidable consequence. The amount of self-straining increases with the amount of elastic equalising. As a rule (not quite without exception), the ratio of elastic deformation accompanying a definite amount of plastic yielding decreases with increase of the temperature. The amount of internal strains therefore will, other conditions being the same, generally increase with decrease of temperature at which unequal flow is brought about, and will be more pronounced in cold-working than in hot-working.*

It is the question of *internal strains caused by cold work* which I propose to discuss somewhat more at length, giving only some occasional references to phenomena produced by hot-working. Let the springs in Fig. 1 be replaced by three metallic bars of equal initial length, and which by different degrees of cold-working are permanently stretched to the lengths l_1 (bars I and I') and l_2 (bar II), l_2 being in excess of l_1. Suppose the three bars coupled, as in Fig. 2, so that they are forced to equalise to the same length l. A system with internal strains will result.

A similar effect can be obtained on unequally stretching out in the cold a bar such as in Fig. 3, so that the core II,

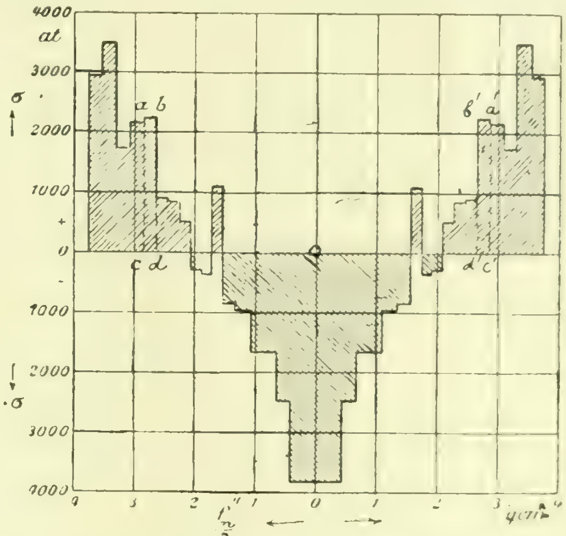


FIG. 6.—COLD-DRAWN NICKEL STEEL BAR.
Portion A.—Distribution of internal strains.

under the influence of a stronger degree of cold-stretching, tends to assume the greater length l_2, whereas the outer layer I, subjected to a less degree of cold-stretching, is inclined to take the length l_1 less than l_2. On account of the two portions I and II being coupled together by cohesive forces, they must agree upon one common length l, thus giving rise to internal strains, if, as generally will be the case, the plastic yielding of the substance of the bar is accompanied by a certain degree of elastic deformation. In the case under consideration, the outer layer I is under tension, the core II under compression strains. If, on the contrary, the portion I is subjected to more severe cold-stretching than the core II, the case is reversed; compression strains result in the surface layer, and tension strains in the core.

The former case is, as far as can be deduced from the experimental work at hand, realised by cold-drawing, the latter by cold-rolling and cold-hammering. In the process of drawing the superficial layers of the metal are kept back by friction in the drawing-die, whereas the core is stretched in a higher degree. In cold-hammering, however, the superficial parts of the metal are subjected to the immediate effect of the blows, the core of the substance playing to a certain degree the part of an anvil. Thus the flow is stronger in the surface layers than in the core.

* An exception is, for instance, to be noted in the case of steel, for which the most critical range for producing self-straining due to unequal flow is at the so-called "blue heat," viz., about 200° to 300° C.

It is by no means a hitherto unknown fact that cold-working may induce internal strains in metallic substances. Various observations made in practical engineering pointed to this direction; for instance, the warping of cold-drawn metal bars on being machined in a certain way. But I venture to say that the question wants much more elucidation than has been brought about by occasional observations and frequent serious troubles, the causes of which have not been examined systematically and thoroughly, and have even been misunderstood, as far as can be concluded from publications. I need only make reference to the various theories proposed with regard to the so-called "season-cracking" of brass and other copper alloys, which often has been ascribed to mysterious crystallisation phenomena, existing only in the fancy of certain persons. I, therefore, am inclined to think that the results of real measurements of internal strains will not be without interest to those concerned in the manufacture of cold-worked metals.

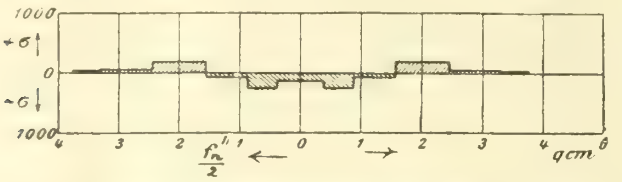


FIG. 7. COLD DRAWN NICKEL STEEL BAR.
Portion B. Distribution of internal strains in the bar after annealing at 850° C. σ = stresses in kg. per cm. (1,000 kg. per cm. = 14,200lbs. per sq. in.).

The first case, which gave the impetus to the researches in question, was the cracking of steam-turbine blades made of high per cent. nickel steel (about 25 per cent.). The blades were shaped as shown in Fig. 5, with rather fine edges on both sides. They were not subjected to external forces which could account for the serious cracking on the side A of the blades, as illustrated in Fig. 5, nor could microstructure and analysis give any clue as to the cause of the failure. The blades had received their final shape by the process of cold-drawing. In order to get some idea of the magnitude of internal strains in cold-drawn bars of high-nickel steel, a rod of this alloy was procured with the following analysis:—

	Per cent.
Nickel	25·1
Carbon	0·3
Silicon	0·26
Manganese	0·73
Phosphorus	0·012
Sulphur	0·022
Copper	0·070

The hot forged cylindrical bar had been reduced from 34 mm. diam. to 31 mm. by cold-drawing without intervening reheating; the reduction in section is 20 per cent. One portion A of the bar was subjected to the measuring method described above, the results being plotted in the diagram Fig. 6. In this the ordinates, measured on both sides of the horizontal zero line, indicate the magnitude of the longitudinal internal stresses, σ_n (in kilogrammes per square centimetre) prevailing in the original bar in a cylindrical layer n of external diameter d_{n-1} and internal diameter d_n (as shown in Fig. 4). It would seem adequate, to take the radii $d_{n-1}/2$ and $d_n/2$ as abscissæ, defining the position of the nth layer within the bar. In the diagram Fig. 6, however the abscissæ for this layer are $f''_n/2 = \frac{\pi}{8} d^2_n$ and $f''_{n-1}/2 = \frac{\pi}{8} d^2_{n-1}$, that is half the sectional area of the respective cores left after the layer n and $n-1$ have been turned off. Since f'_n the section of the nth layer is $f'_n = f''_{n-1} - f''_n$ the basis cd of each rectangle $abcd$ (Fig. 6) measures half the section f'_n of the nth layer, and the ordinate $ac = bd$ represents the internal stress σ_n which prevailed in this layer. This manner of proceeding affords the advantage that the shaded areas $abcd$ and $a'b'c'd'$ in the diagram, representing together the product of the stress σ_n by the area f'_n of the nth layer in which this stress prevails, immediately indicate the internal forces $P_n = \sigma_n \cdot f'_n$. The shaded areas above the horizontal zero-line represent tension forces, those beneath that line compression forces. Since, in the state of equilibrium, the tension and compression forces must balance one another, the shaded area above the zero-line must be equal to the shaded area below this line. The sum of the shaded areas gives some idea of the potential energy stored up in the bar in consequence of its internal strains.

As will be seen from the diagram Fig. 6, very severe internal strains existed in the cold-drawn bar in the direction of its axis, tension strains in the outer layers, compressive ones in the central portions. The maximum tension stress amounted to 3,500 kgs. per square centimetre (about 50,000lbs. per square inch), the maximum compressive stress to 3,810 kgs. per square centimetre (about 54,000lbs. per square inch).

In order to check the accuracy of the measuring method employed, another portion B of the same bar was heated one hour at a temperature of 850° C., and left to cool slowly. Internal strains must be removed by this process. The result of subsequent measurements is given in diagram Fig. 7, which shows that the shaded areas corresponding to the forces in equilibrium within the mass of the bar have become very small, indicating the magnitude of errors involved by the method on the assumption that no strains whatever have been left in the annealed bar, and that none have been produced by the manner of cooling.

It is obvious that in addition to the longitudinal strains in the direction of the axis of the cold-drawn bar, there must also exist transverse internal strains. In order to measure these, it would be necessary to bore out the bar from within, taking off successive layers and measuring the variation of the outer diameter after removing each layer.

In the above-mentioned turbine blades of 25 per cent. nickel steel, measurements of the internal longitudinal strains were made, which showed that the maximum of internal tension stresses prevailed at A (Fig. 5), the maximum of compressive stresses in the neighbourhood of the sharp edges. The internal tension stresses were of an amount not much inferior to the ultimate tensile strength of the steel. It is obvious that even trifling additional stresses due to external forces, or to any other cause, may raise these stresses to the tensile limit and so give rise to the cracks shown in Fig. 5.

It would be erroneous to draw the conclusion from the above that high per cent. nickel steel was unsuited for turbine blading, since it is possible to manufacture blades of this material without the serious strains mentioned. Later on the way in which this may be achieved will be referred to.

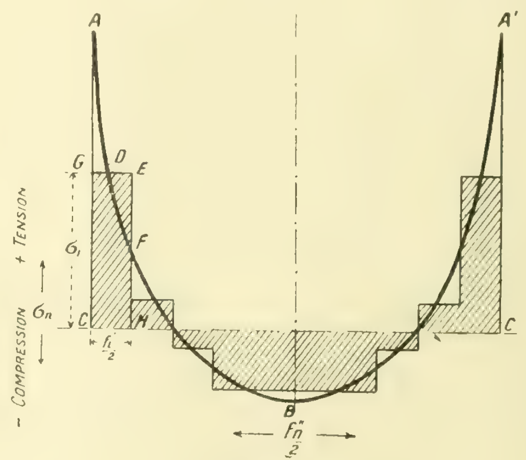


FIG. 8.

Some additional information may be given as to the meaning of the strain diagrams, such as Figs. 6 and 7. The stress $\sigma_n = ac$ (Fig. 6) need not be constant throughout the layer cd, as would appear from the staircase-like shape of the shaded areas. σ_n indicates only the average value of all the stresses in the layer cd. For instance, the curve ABA′ in Fig. 8 might be assumed to represent the true distribution of stresses within the bar under consideration. This true curve could only be found experimentally if the number n of the successive layers removed by turning were infinite and the thickness of each of these layers infinitesimal, a requirement which cannot be practically met. If, for instance, the sectional area

of the outer layer I be f'_1, as shown in Fig. 8, the average value of stress σ_1 would be found equal to the ordinate $CG = EH$ of the rectangle erected on the base $CH = f'_1/2$. In fact, the distribution of stresses within the sectional area $f'_1/2$ is represented by the curve ADF. Thus, in the surface film the high stress CA may exist, which is much in excess of the average value $CG = \sigma_1$. The latter results from the condition that the area AGD must be equal to the area DEF.

It is of importance that the tension stress in the exterior layer may be much higher than the measured average stress σ_1. There exists, therefore, the possibility that in the case of Fig. 6 the maximum tension stress in the surface layer of the cold-drawn bar may exceed the value 3,500 kgs. per square centimetre by a certain amount. The possibility must even be reckoned with that in the extreme surface layer the tension stress may approach the ultimate tensile strength of the material. It is therefore no matter for surprise that, in certain cases, even very small additional strains (due to unequal cooling or heating, slight injury to the surface, mechanical load, and so on) can eventually lead to surface cracks and fracture.

(To be continued.)

STANDARD MACHINE-TOOL MOTORS.*

BY CHARLES FAIR.

DURING past years much progress has been made in the standardising of certain machine parts, with results advantageous both to the machine manufacturer and user. For a long time it has been recognised as desirable, at least on the part of a number of the machine-tool builders, that something be done towards standardising certain motor dimensions, speeds, &c., for machine tool drive. For the past five or six years attempts have been made to standardise certain dimensions and speeds for machine-tool motors, but these attempts have failed for various reasons. It would be of little use to analyse these past failures. Unquestionably there should be first of all a better understanding on the part of the machine manufacturer and the motor manufacturer of each other's difficulties; and much work is essential before material progress along the line of standardisation can be accomplished. With this in mind, I have prepared an outline which I think fairly presents the situation from the view point of both sides, and which must be considered if results are to be obtained. This outline is published herewith.

It could not be expected that the electrical manufacturers would change existing standards of motor dimensions or speeds, nor do I believe it would be desirable; but I see no reason why, if the machine manufacturers in conjunction with the motor manufacturers will give the subject the consideration it warrants and do their part towards bringing about a better understanding, the motor manufacturers in turn cannot incorporate, at least in part, some of the dimensions and the speeds when bringing out new lines of motors. Obviously it would be just as impossible for the various motor manufacturers to design their motors to a single set of dimensions as it would be for the machine manufacturers to design their machines to a single set of dimensions. Notwithstanding this, however, much can be done to improve the situation. For the sake of convenience, I have divided the outline into five parts, namely, speeds, shafts, frame, method of drive, and general.

Under the heading of speeds you will note that there is an almost endless number of combinations available, but from this great variety certain speeds should become the logical ones for the majority of drives. The direct-current constant-speed shunt-motor speed, for instance, might be that of the alternating-current 60-cycle motor. Alternating-current and direct-current motor speeds should be given in terms of full load or possibly in terms of both no load and full load. It is, of course, understood that the cycles fix the alternating-current motor speeds, except as modified by slip, &c. Adjustable-speed motors would naturally be higher in speed on the highest speed than a constant-speed motor, on the theory that the adjustable-speed motor would only run a percentage of the time on high speed. Adjustable-speed motors are more generally geared, and their speeds should be governed by the proper gear speed.

There should be little difficulty in arriving at a proper shaft diameter and key for a given horse-power and speed motor. The length of shaft might offer some difficulty. A uniformity of frame dimensions is obviously impossible, but much can be done to reduce the large variety of dimensions to perhaps two or three sizes per frame. There is, of course, no reason why there should not be a uniform drilling of the feet in the frame. It is not only important but absolutely necessary to consider seriously the item of drive in order to arrive at some basis upon which properly to determine the best

- Speeds
  - Constant / Variable
    - AC
      - Full load
      - Synchronous
      - [illegible] / Power / Voltage
      - Squirrel cage / Slip ring / Internal resistance
      - High torque / Normal torque
    - DC
      - Full load
      - Light load
      - Voltage / Shunt / Compound / Series
  - Adjustable / Variable
    - DC
      - Voltage
        - Shunt
        - Comp
        - Series
    - AC
      - Brush shifting
        - Shunt characteristic
        - Series characteristic
      - Multi speed
        - Constant horse-power
        - Constant torque
      - Slip ring
        - Multi speed
- Shafts
  - Diameter / Keyway / Length
    - Gear
      - Involute
        - Steel
        - Rawhide
      - Herringbone
    - Chain
      - Bevel, worm [thrust]
    - Coupling
    - Belt
- Frame
  - Bottom of feet to center line of shaft
  - Shoulder on shaft to center line of feet
  - Overall dimension of feet
  - Drilling of feet—dimensions and sizes of holes
- Drive
  - Gears
    - Peripheral speed
      - Normal for constant
      - Maximum for adjustable
      - Cost [illegible]
    - Minimum number of teeth, pitch, face, bore
  - Chain coupling, belt
  - Reversing, non reversing, slow down, brake
    - Dynamic
    - Solenoid
    - Mechanical
  - Range of speed required
    - Cost
    - Size of motor
  - All geared drive for constant speed
  - Balance of rotating parts
  - Change gears—motor speed overlapping
- General
  - Uniformity marking motor terminals
  - Uniformity control diagram
  - Protection of live parts
  - Covers for end shields, etc

speeds, shaft dimensions, &c., to standardise. Uniformity in making motor terminals, wiring diagrams, protecting live parts, &c., are of advantage to all concerned.

The machine user will derive considerable advantage from the standardisation of motor parts as well as the machine manufacturer. The importance of the motor-driven machine tool with relation to production has become such that the method of applying the motor to the tool, in my opinion, warrants far more attention than has been given to it in the past by some of the tool manufacturers; and I trust that before another year elapses the motor manufacturers and the machine manufacturers will each have a better understanding of the difficulties of the other, and that much will have been accomplished toward establishing suitable standards.

* Paper read at the April meeting of the National Machine Tool Builders Association, at Worcester, Mass., U.S.A.

The Junior Institution of Engineers: North-western Section.—A meeting of this section was held in Manchester on the 21st inst., when a paper on pattern-making was read by Mr. T. R. Schofield. The question was dealt with from the practical point of the man who makes the patterns, having due regard to the fact that patterns are the tools of the moulder, and economy in the pattern-shop may mean extravagance in the foundry. Sample patterns of various materials were exhibited, and novel operations for the quick and cheap production of patterns were described. One method of making a worm had reduced the time of manufacture from two days to 30 minutes.

FAILURES OF HEAVY BOILER SHELL PLATES.*

BY SIDNEY A. HOUGHTON, A.M.INST.C.E. (SHIP AND ENGINEER SURVEYOR, MARINE DEPARTMENT, BOARD OF TRADE).

(*Concluded from page 490.*)

IT has been pointed out by Mr. David Colville and others that severe internal stresses may exist in heavy plates, as their stiffness prevents them from buckling in the manner that thin plates do when the rolls are not true, and there is little doubt that this cause is a factor, and possibly sometimes the principal one, in producing failure. Unfortunately it seems scarcely possible to ascertain the amount of these stresses, or indeed to find out when they exist in a plate in most instances, but it has been supposed by some investigators that the bubble-shaped crack which so frequently occurs in defective plates is due to this reason. A typical example of this crack is shown in Fig. 9; it is a type which is nearly always at right angles to the direction of rolling, and perpendicular to the surface of the plate. As a rule the surfaces of these cracks are oxidised and are fairly flat, and their depth varies from one-half to three-quarters of the thickness of the plate. It would seem that, if they are the result of relieving internal stresses, the latter reach a maximum at some point below the surface.

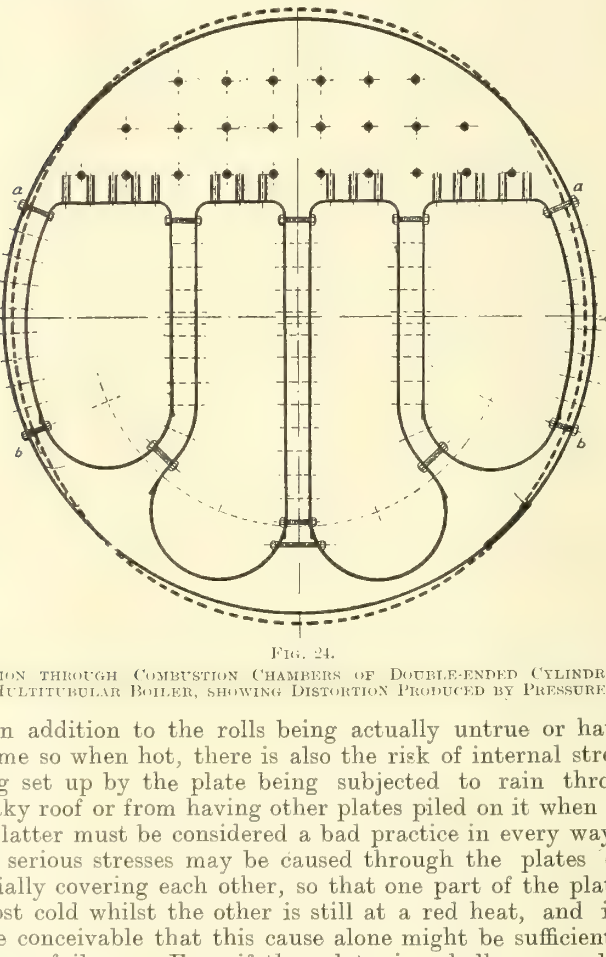


FIG. 24.
SECTION THROUGH COMBUSTION CHAMBERS OF DOUBLE-ENDED CYLINDRICAL MULTITUBULAR BOILER, SHOWING DISTORTION PRODUCED BY PRESSURE.

In addition to the rolls being actually untrue or having become so when hot, there is also the risk of internal stresses being set up by the plate being subjected to rain through a leaky roof or from having other plates piled on it when hot. The latter must be considered a bad practice in every way, as very serious stresses may be caused through the plates only partially covering each other, so that one part of the plate is almost cold whilst the other is still at a red heat, and it is quite conceivable that this cause alone might be sufficient to produce failure. Even if the plate is wholly covered by another it is possible that it may be maintained at the dangerous temperature of 700° C. for some time, thereby producing brittleness by partially turning the pearlite into cementite. Owing to the circumscribed space in some works it is difficult to avoid piling altogether, but it would be well that, if it is done, it should be confined to plates which will be afterwards heated in the course of manufacture. In any case, the author is of the opinion that the only satisfactory way to ensure that heavy plates are as free as possible from internal stresses is to anneal them. This will remove the effect of finishing at too high a temperature (see Fig. 10), or too low (Fig. 4), and also the results of slow cooling at an improper temperature (Fig. 16), and as these evils are not revealed by the usual tests it is the more important to ensure that they do not exist. Although it might seem a simple matter to anneal a mild steel plate, yet experience has shown that there are several pitfalls to be avoided. In the first place, the most suitable temperature has not been definitely settled; it is true that there have been many laboratory demonstrations, and that one or two practical papers, such as that by Mr. Campion, have been read, but it does not appear that the subject of heavy mild steel plates has been dealt with, or if so, that it has come to the knowledge of at least some works. The author has seen the results of a series of experiments in this connection which have recently been made at a very progressive steel works, but these, being confidential, cannot, of course, be given in this paper; but it is to be hoped that perhaps one of the Carnegie scholars may find time to deal with this practical but comparatively simple subject. One point of importance may be mentioned, which is that mild steels containing a fairly high percentage of phosphorus require very much more drastic annealing than those with a small percentage; it is indeed remarkable how very persistent is the structure of a moderately high phosphorus steel. In the case of plate B4, in which the pearlite was partly in the form of cementite, even after annealing a small piece for half an hour at 850° C. comparatively little difference was made in the structure.

* Paper read before the Iron and Steel Institute, May, 1914.

It is also of great importance that the whole plate should be raised to the same temperature when being annealed, and although this should be the first axiom in annealing it is not altogether an easy matter to effect with large plates, and some of the older annealing furnaces are not free from suspicion in this respect. Plates B2 and B4 are prominent examples of the harm which can be done in this way, and the author has frequently seen others withdrawn from the furnace in which the colour varied very considerably. Annealing may also be easily abused by soaking a plate to bring its tonnage down, and there are some people who apparently see no evil in this if the elongation is satisfactory, as it generally is, forgetting that certain forms of brittle material are quite satisfactory judged by the elongation. Owing to the readiness with which this measure of ductility can be applied it is in almost universal use, but the fact alone that bend tests are also required with steel plates should be an indication that it is not an absolute determination of the suitability of the steel. Unquestionably the use of the pyrometer might be extended in dealing with the annealing of such important material, and it is difficult to believe that the trifling extra expense would not be soon repaid by the avoidance of expensive rejections.

In most of these plates the chemical composition is not abnormal, and would not be objected to for most purposes, that is, the sulphur and phosphorus do not exceed 0·06 per cent., or if they do, it is only by a small amount. In large plates, however, where the work done on them is comparatively small, it is necessary for the metal to be exceptionally pure, and it must be remembered that both the major and minor segregations increase with large masses of steel. Phosphorus and sulphur unfortunately segregate so much that, although a certain percentage would be harmless enough if distributed evenly, it may produce failure owing to these segregations. For these reasons it is suggested that 0·05 per cent. should be the limit for phosphorus, especially if there is an appreciable quantity of arsenic present; the latter element is one whose bad qualities are not always fully realised, and it is a good plan, as adopted at at least one works, to add the quantity of it and phosphorus together in estimating the suitability of the steel, in which case the total should not exceed, say, 0·06 per cent. It also appears that phosphorus has a strong tendency towards turning the pearlite into cementite, which occurs also if the plate is heated for some time at a temperature below 700° C.

It is sometimes urged that, owing to the progress of knowledge and increased skill in manufacture, the nominal factor of safety of marine boiler shells might be reduced. It is also argued that the joints themselves do not fail, and that the shell plate itself has a fairly large factor, *e.g.* with a nominal factor of 4·5 for the joints and a percentage strength of 85 the theoretical factor of safety of the shell plates would be nearly 5·3. So far as the steel itself is concerned, the facts given in this paper should be a sufficient answer, but it is well also to remember that the calculation of the mechanical stresses in boilers is not so simple as is often supposed. The boiler shells themselves, though circular, and even when fitted with double butt straps, are, as a rule, subjected to additional

stresses than pure tensile ones. For instance, in the case of many double-ended boilers the shell plates are tied horizontally only by the combustion chamber stays, with the result that when subjected to pressure they tend to become oval, or, more strictly speaking, of the form shown in Fig. 24. This movement is quite perceptible, especially when comparatively thin high tensile plates are used, and has caused distortion in the combustion chambers. It is evident, therefore, that the shell plates themselves must be subjected to somewhat complicated stresses at the points *a* and *b*. There is also a considerable barrelling action, due to the ends of the shell being immovably fixed to the end plates, this being most severe in boilers in which only one strake of shell plating is fitted.

With regard to manholes, the conditions are much more severe in practice. The usual plan is to fit a doubling plate, the net section of which is equal to that of the plate cut out, but this is only a rough approximation, and there is little doubt that the factor of safety of the solid plate is reduced at these parts. It has been shown by Mr. John Smith, R.C.N.C., in his paper on "Stresses in Ships," read before the British Association in 1906, that the stresses round openings in plates approximate to those of the lines of flow of a stream of liquid flowing round a similarly shaped obstacle. In the case of manholes these increase greatly at the edge of the opening, and in manholes of the usual shape (Fig. 25) they are not necessarily at a maximum at the minor axis. Another and even greater reduction of strength at the manholes may be caused by the method of riveting the compensating ring. When these are of considerable thickness, such as are necessary with heavy shells, and especially when flanged rings are used, it is extremely difficult to make them accurately fit the curve of the shell plates. Consequently, when being riveted by the modern powerful hydraulic machine considerable creeping takes place, and it depends largely on the order in which the rivets are put in whether tensile stresses are or are not produced in the shell plates. Suppose, for instance, that riveting is begun at the ends of the major axis, rivets being alternately placed at each end, then as the riveting approaches the minor axis the compensating ring will tend to spring off and an enormous tensile stress will be produced in the shell plate, which stress, it must be remembered, will be in addition to that produced by the pressure of steam. This is about the worst result possible, but, if not carefully done, effects of the same nature can be readily produced by other methods of riveting. The proper manner to rivet is evidently to begin at the minor axis, and rimer the rivet holes when creeping occurs. It may be observed that in plates C1, C2, and C3, where fracture occurred at the manhole, the edges of the plate remained open, and although it is impossible to prove how much of this movement was due to internal stresses and how much to the effect of improper riveting, yet it is probable, in the author's opinion, that the latter had in these instances at least as much influence as the former.

In connection with boiler-shop work, it may be observed that the modern method of bending plates in a vertical roller-press seems to be undoubtedly more severe on the plates than the old method of bending in the rolls. With the former method plates are sometimes bent in three passes, or even less, which would be impossible with the older apparatus.

The effect of shearing on the edge of the plate is another element which has to be taken into account in considering failures, and indeed in some cases the fracture has been attributed entirely to this cause. Though the author is of the opinion that this cannot be said of the instances quoted in this paper, yet it is undoubtedly true that the distance to which the deformation produced by shearing penetrates is not fully recognised by many boiler makers. The amount which should be removed will vary according to the state of the shears, but by testing some sections with Shore's Sclerometer, Mr. A. McCance, of Messrs. William Beardmore and Co., Parkhead, has ascertained that the hardness produced by shearing extends to a distance of about half the thickness of the plate with the shears in average condition. This is considerably more than is usually assumed, an addition of only a quarter of an inch for shearing being a common allowance; it would therefore seem that this should be considerably increased. It has been suggested that the best remedy for this danger would be for the plates to be ripped to size once for all at the steelworks, and undoubtedly this will altogether remove trouble from shearing effects, and would save expense, whilst at the same time the test-pieces could be relied upon to be free from defects, it being well known that with thick plates these have to be made very wide or else cut out by the machine to avoid the prepared part being affected by the shearing. The chief disadvantage of the proposed procedure would be the difficulty of ascertaining if segregation existed in the plate, this being generally easily detected on the sheared edges, but it is difficult to see if the plate is machined. In practice this is of importance, especially as segregation occurs, as a rule, away from the parts where the usual tests are taken, but this deficiency might be overcome by taking additional tests, and the balance of advantage would be in ripping the plates. It might be mentioned that this is occasionally done with very thick plates in some works, especially when the margin for test-pieces is small, so as to avoid injury to the latter, but even then an allowance has generally to be left so that the boiler makers may take the responsibility of reducing the plate to its final dimensions.

As stated above, the usual test-pieces are taken from those parts where segregation is likely to be absent; they are also the parts which are never finished at an excessive heat, so that they will generally give better, or at least as good, results as any other part of the plate. It may be here mentioned that tests taken close to the edge can give a ton or more tensile strength than the body of the plate, a fact which is shown by many of the examples given in this paper. The position of the test-pieces follows those made from iron plates, and in the early days of the use of steel, segregation was little heard of—at any rate, by those outside the steelworks; moreover, the plates were small and thin, and trouble from this defect did not often arise. Certain inspecting societies have required cross tests as well as longitudinal ones, and although these, as a rule, are also taken at the corners, they do show to some extent whether the steel has had insufficient work on it, and whether it is fairly free from sulphur and blowhole flaws which defects produce little or no effect on the longitudinal tensile tests. The Board of Trade have, however, for some time instructed their officers, when the proportion of the ingot used is large, to take cross tests from the centre of the ends of plates, with a view of detecting segregation, and experience has shown that this test is a very effective one. If the plates are cross-rolled, so that the longitudinal axis of the ingot corresponds with the transverse one of the plate, these tests must obviously be taken from the centre of the sides. A fair proportion of heavy plates have failed under this test, and this is undoubtedly due to the fact that the size of the ingots has not increased in proportion to that of the plates; indeed, in some works it is impossible to increase further, owing to the restrictions imposed by the cogging and rolling mills. Even if the mills are large enough, their strength may be inadequate, with the consequence that it is necessary to roll down the slabs at an excessive temperature, under which circumstances the segregate may be so fluid as to be squeezed out of the end of the slab.

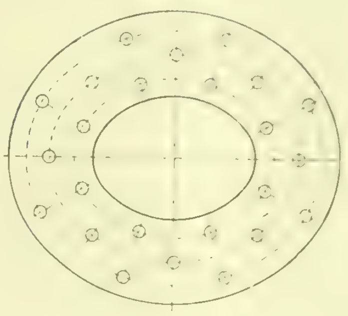


FIG. 25.—COMPENSATING RING FOR MANHOLE.

It is sometimes suggested that segregation cannot be very harmful, as the inferior metal is situated at the neutral axis of the plate, but this argument does not take into account the stresses induced when removing any want of flatness in the plate. Moreover, if we consider the effect of segregation in the plate when being rolled, it will be seen that it may be of serious importance. Even if the segregate is not actually fluid it will be in a more pasty condition than the remaining metal, so that that part of the slab which contains it is somewhat in the condition of a box containing a more or less fluid interior. It will be seen that under these conditions the flow of metal becomes complex, and abnormal stresses may be set up by the rolling mill. Apart from this, the segregate is inferior and brittle metal, which should at all costs be kept out of such important articles as shell plates, and that it

is harmful is shown sufficiently by the failures of plates C1, C2, and C3, through the manhole, so that it is not necessary to elaborate this point any further.

Although not mentioned in the heading "Probable Causes of Failure," there is one which is, as it were, a master cause, and that is insufficient work on the steel due to the plates being made from too small an ingot. The exact proportions are not available in all the cases, but apart from the instances given in this paper the author has ample experience as to the evil effect of using too small ingots. In the first place, there is the risk of including part of the major segregate, the position of which varies, as is well known, but from experience it is found that if the weight of the plate as cut much exceeds 45 per cent. of the ingot, there is an increasing probability of including part of it, and with 60 per cent. the probability almost becomes a certainty. It must be understood that ingots of the usual proportions are considered, and that about 5 per cent. is cut off the bottom ends. If a larger proportion is cut off there will naturally be more danger of approaching the major segregate with the plate slab, and for this reason it is desirable to allow a fair margin with the percentage. With special methods of casting a higher proportion could doubtless be used, but this is a matter which rests with the steel maker. Even if this is done the objection still remains that insufficient work is put upon the material, and this is a point of the greatest importance. In the first place work removes to a large extent the deleterious effects of the minor segregations of phosphorus, and, secondly, it makes the material more reliable and ductile. This latter quality is unfortunately only partially measured by the elongation of the tensile test-piece, for, as is well known, it is possible to get steel castings giving as good results so far as strength and elongation are concerned as rolled steel, yet no one would care to stand in front of a boiler under steam if the shell plates were made of cast steel. The percentage of reduction of area is a more reliable measure of true ductility, but to obtain the necessary particulars considerably more time would be required than is usually available.

To some extent the work put into the plate may be estimated by the chemical analysis. It is recognised in steelworks that the carbon content must be increased with the thickness, which means that the work done on the material is reduced, even allowing for the fact that thick plates are generally finished at a higher temperature than thin ones. The author suggests, therefore, that a limit of carbon and manganese might be required for each tensile limit in the same way that the amounts of sulphur and phosphorus are restricted. Plates Nos. A11 and B3 may be quoted as examples of the want of this restriction; in these plates the carbon was 0·35 and 0·3 per cent. for a thickness of $1\frac{5}{16}$ in. and $1\frac{5}{8}$ in. These quantities approach those allowed for steel castings, and indeed the structure of these plates was similar to that material. The longitudinal tensile tests of these plates gave, however, quite satisfactory results, but both plates are typical of the use of two small ingots with a high finishing temperature.

To sum up, it would appear that in order to eliminate the risk of failure the following points should be complied with: (1) Large ingots; the proportion of the weight of the plate as cut not to exceed about 45 per cent. of that of the ingot. (2) Effective annealing, the pyrometer being always used, and a record kept of the temperature to which each plate was subjected as well as the length of time it was in the annealing furnace. (3) Low phosphorus, not to exceed 0·05 per cent., or with arsenic 0·06 per cent. (4) Inspection of all parts which require dressing by an independent inspector, no plate to be accepted at the boiler works which has been dressed, and has not been stamped by the inspector on the dressed part. (This has been done by the Board of Trade for many years.) (5) Occasional transverse tests to be taken from the centres of the ends or sides of the plates corresponding with the longitudinal axis of the ingot.

The Board of Trade have willingly given permission to use the official records for this paper, in the hope that the particulars given will help to prevent failures in future. The author desires to thank Mr. David Colville for granting the use of the fine photo-micrographic apparatus at Dalzell Works, and Mr. H. J. Pinkerton, chief chemist at those works, for taking many of the photographs given in this paper.

A GERMAN DESIGN OF WATER-TUBE BOILER AND SUPERHEATER.

THE accompanying illustrations show a combined arrangement of water-tube boiler and superheater, the invention of the Vulcan Works, Hamburg, Fig. 1 being a vertical section and Fig. 2 a view in section taken along the line A B in Fig. 1, the long arrow indicating the path followed by the furnace gases or products of combustion. The arrangement comprises an upper drum C, two lower drums D, and the water tubes E. Inside the boiler the superheater coils F are built into the space formed on one or both sides of the nests of water tubes E by omitting some of the water tubes. The inner and outer walls G and H are formed by arranging the water tubes close together, the inner row of tubes G being

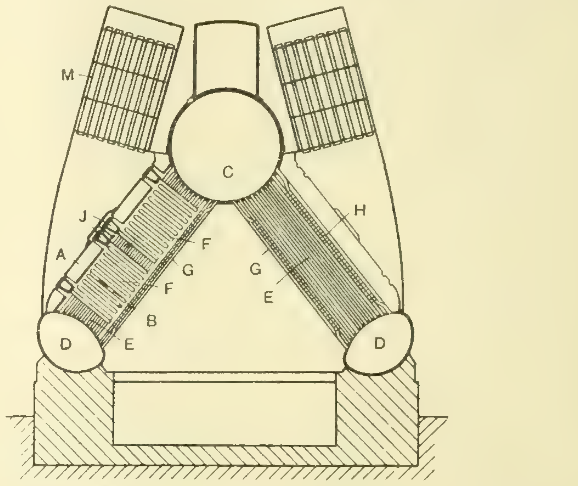


FIG. 1. SECTIONAL ELEVATION OF WATER-TUBE BOILER AND SUPERHEATER.

adapted to prevent direct contact of the furnace gases with the superheater. The superheater coils are disposed in vertical planes and open into horizontally arranged steam chambers J, as shown on the left-hand side of Figs. 1 and 2.

Upon the right-hand side of Fig. 2 a second constructional form is shown in which the heat yielded up by the hot gases is still further increased by special water-tube walls K inserted alternately from both sides. The gases are caused to flow through the nest of tubes by a long path, and they are thus afforded an opportunity for a comparatively long period of time of transmitting their heat to the water tubes. Further, in this case also an automatic circulation of the water may be obtained without the incorporation of a separate return pipe. Owing to the position of the steam chambers J, which are readily accessible from the exterior, the superheaters are rendered capable of being inspected and cleaned without the necessity for tedious dismantling operations. It is possible to obtain any predetermined degree of superheating according to the longitudinal dimensions of the superheater and the manner in which it is built.

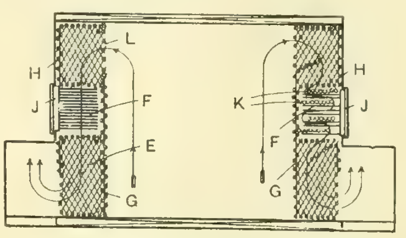


FIG. 2. SECTIONAL PLAN OF WATER-TUBE BOILER AND SUPERHEATER.

The wet steam, coming from the boiler, enters the superheater by way of the steam chambers J and, flowing through the superheater tubes, becomes superheated. The steam then passes through the other steam chambers J to the main steam pipe. From the grate the hot gases pass upwards and rearwards and entering through an opening L at the rear of the inner wall G, they pass between the first nest of water tubes E The gases flow between these tubes from rear to front and in their further passage encounter the superheater tubes or coils F, about which they flow, thence passing between the second nest of the water tubes and finally through an opening at the front end of the outer wall H into the smokebox. It is advantageous to arrange a preliminary air heater M behind the boiler heating surface, whereby a specially efficient utilisation of the hot gases is ensured even after they have passed the water tubes.

BOOK REVIEWS.

The Gas Turbine. By Norman Davey. London: Constable and Co. 9in. by 6in. 248 pp. Price, 15s. net.

Although the gas turbine has not yet become a commercial machine, a good deal of experimental work and inventive ingenuity has been expended in the expectation of its being eventually realised. The difficulties in the way are undoubtedly great, and whether or not they will ultimately be overcome we will not attempt to prophesy. The theory of the problems involved are interesting and instructive, but though they have been touched upon more or less by many writers this is, we believe, the first British text-book to deal in a comprehensive manner with the subject. This is the justification put forward by its author in the preface for adding another to the long list of volumes on thermodynamics, and its special applications to this particular field have furnished him with ample material. It is, of course, inevitable from the nature of the work that the class of readers will be small and confined mainly to students or the heads of firms on the search for new outlets for constructive skill and enterprise. The author has taken his task seriously, and those interested in the future developments of turbines will find the book of interest. We trust their number may be sufficient to reward him for the pains and labour he has evidently devoted to his task.

* * *

Practical Ironfounding. By Joseph Horner. Fourth edition. London: Whittaker & Co. 7½in. by 5½in.: 409 pp. Price, 5s. net.

The author of this volume has been long known as a writer on pattern-making, of which he has had wide experience, and as the pattern shop is intimately associated with the foundry he has inevitably had considerable experience with the latter also, and therefore may be regarded as well equipped for dealing with many of the practical sides of moulding. The fact that the book has run into a fourth edition is obvious proof that it has met a want, and we can believe, from the practical knowledge displayed and illustrated, that the volume is a popular one, especially with students. The practical work of foundry operation is very fully dealt with, though the metallurgical side is rather briefly treated; but as this is a field big enough for a volume in itself the author has probably acted wisely in confining himself to the general outlines of cupola work. Taken altogether the book is a sound, practical treatise, and we have pleasure in recommending it.

* * *

Modern Workshop Practice. A Manual for Students and Apprentices in Technical Institutes. By Ernest Pull. London: Crosby Lockwood & Son. 7¼in. by 5½in.; 308 pp. Price, 5s. net.

The increased attention given by technical institutes to workshop training has brought into existence quite an army of students interested in the theory of machine tools and manipulative processes. There are already a number of books dealing with engineering workshop practice, but the one under notice bears sufficient freshness as regards matter and treatment to warrant a place amongst them. The constructive principles of the machine-tool and fitting shop are clearly explained and illustrated, and this in a way that can be readily followed by the apprentice or elementary student. The book is, of course, mainly descriptive, and the arithmetic never travels beyond simple fractions. The descriptive information is also accompanied with numerous tables, which help to make the volume more self-contained.

* * *

Gas and Oil Engine Management. A Practical Guide for Users and Attendants. By M. Powis Bale. London: Crosby Lockwood & Son. 7½in. by 5in.; 164 pp.

* * *

Electrical Wiremen's Work. A Practical Handbook. By J. H. Havelock, head of Electrical Engineering Department, Chatham Technical Institute. London: Crosby Lockwood & Son. 7¾in. by 5in.; 332 pp. Price, 5s. net.

THE FOUNDRY CUPOLA.*

BY E. L. RHEAD, MANCHESTER.

In the design of a piece of apparatus for any given purpose it is first necessary to study the conditions under which it will be used and the variations in condition possible as the result of accidental and functional changes, and also its connection with and dependence on other appliances with which it will have to act in conjunction, and by which its efficiency will be largely affected. It will be necessary to consider its position in the scheme, whether it occupies a primary or subsidiary place, and in the former case to build the scheme round it, or in the latter to build it in, having first shaped it in size and form for the position intended.

In melting iron for the foundry the cupola holds the position of the first importance, and its behaviour will determine to a large extent the success attained not only in this particular department of foundry work, but also in the general success. The object aimed at in the successful operation of a cupola is to provide a supply of molten iron sufficiently hot for the purpose in hand as rapidly or as regularly as possible, as the case may be, with the minimum of cost both in labour and fuel and attention—a reliable appliance whose working can be reduced almost to a standard, and the results relied on with certainty, so long as working conditions do not depart from the normal to a greater extent than is likely to occur from the usual minor accidental circumstance of daily work. It may be called upon to supply, during the same run, metal of a different quality for different purposes, or it may run for long periods on material of the same character. Special features may be necessary in the latter case, but in all circumstances the primary object is to secure rapid, hot, and economical melting.

In order to do this it will be necessary first to attain a temperature high enough to melt and superheat the metal sufficiently to enable the mould to be filled while yet the metal retains all its constituents in perfect solution, so that cooling and solidification can proceed regularly. Second, to generate sufficient heat to melt the metal and raise its temperature to the desired limit with as little fuel as possible. The amount of heat required for these purposes is a perfectly definite amount, depending only on the melting point, and the specific and latent heats of the metal. In this connection it must be borne in mind that the burning of a given fuel can only generate a certain quantity of heat per unit weight consumed under the best possible conditions. This depends on its composition only. Whether this amount is generated depends on how completely the fuel is burnt. Carbon, it will be remembered, burns in two stages—to the monoxide CO, and the dioxide CO_2. The maximum amount of heat is produced by the latter change, but instead of the former change producing a half of the amount, it only produces something less than one-third of the total. It is therefore obvious that the combustion should be made as complete as possible. Complete combustion can only be attained when there is a sufficient excess of air to furnish oxygen. If in the burning of coke or other carbonaceous fuels, there is a *local* excess of oxygen, carbon dioxide may be formed; but if that gas comes into contact with carbon at a sufficiently high temperature—say, above redness—the carbon deprives it of half its oxygen and reduces it to carbon monoxide. Both factors must be reckoned with, viz., temperature and contact. If the temperature is too low to furnish the heat for the reduction,

$$
\begin{aligned}
C + O_2 &= CO_2 + 96{,}960 \text{ heat units} \\
C + O &= CO + 29{,}676 \quad ,, \quad ,, \\
CO + O &= CO_2 + 67{,}284 \quad ,, \quad ,, \\
CO_2 + C &= 2CO - 37{,}608 \quad ,, \quad ,,
\end{aligned}
$$

it will not take place, and if contact of the gas with the carbon does not occur it will remain unreduced. These considerations are of the greatest importance in dealing with the blast, its quantity, distribution and pressure, and also with the rapidity of the gas current passing through the cupola, the size of coke and its quality. Any condition making an increase in the amount of carbon dioxide in the gases passing from the furnace must result from an increased development

* Paper presented at the annual convention of the British [illegible] Association, at Leicester, May 12th to [illegible], 1914.

of heat in the cupola from the coke burnt. It must not be overlooked that the carbon monoxide will, *if still hot enough* to ignite, burn in an excess of air and produce carbon dioxide, as shown above, with the generation of much heat.

Of equal importance is the economical application of the heat generated. In ordinary cases heat is only communicated to one body by another by contact or by radiation. In the case of gases only by actual contact, as gases possess little radiating power, so that in a cupola heating of the metal and other materials must result from (*a*) actual contact with incandescent coke; (*b*) heat radiated from the surrounding coke—but only by the surface coke—if two pieces of glowing coke are one behind the other, radiant heat only reaches the metal from the surface immediately facing it; (*c*) by heat abstracted from hot gases impinging on the surface of the metal. Since the final product of the burning is gaseous, the part played by the gases is of primary importance. By far the greater part of the heat generated in the furnace is first taken up by the gases and by them distributed in the furnace. Consequently any consideration that influences the manner of distribution or the completeness of the contact of the gases with the solid materials in the furnace will produce its due effect on the working of the cupola, irregular distribution leading to imperfect contact and irregular heating with incomplete cooling of the gases and loss of heat. Incidentally, the region of high temperature extends higher in the furnace, either generally or locally, and in some cases the lining of the furnace will suffer.

It has been already pointed out that a certain quantity of useful heat is required to melt the metal and slag in the cupola, and that a certain quantity will be wasted or lost in various ways. That heat may be considered lost which is not transferred to the metal and slag. These losses comprise (*a*) loss by radiation from the casing of the furnace; (*b*) sensible heat carried away by the hot gases from the throat; (*c*) undeveloped heat represented by the carbon monoxide in the gases. To a greater or less extent these are unavoidable, and the cupola will be most efficient in which these losses are reduced to a minimum. In ordinary circumstances the whole of the heat is derived from active combustion, more being carried in mechanically by using a hot blast as in iron-smelting blastfurnaces. A brief glance at these losses will point out some useful conclusions.

Loss by radiation will depend on the temperature of the casing, and will depend on the rate at which heat is conducted to it from the hot interior by the lining. The thickness of the lining and its conductivity will thus enter into the consideration. The latter varies comparatively little for firebrick, but its thickness will, of course, have an effect. The extent of the surface of the casing, compared with the sectional area of the furnace, has a large influence. As the area increases with the square of the diameter and the circumference with the diameter the proportion of surface to capacity rapidly diminishes.

Diameter of cupola.	Sectional area.	Circumference.	Surface. Cubic Capacity.	Cubic capacity feet. Area of surface.
1	0·7854	3·1416	4	0·25
2	3·1416	6·2832	2	0·5
3	7·0686	9·4242	1·3	0·75

Obviously the loss of heat from this cause must be less in the case of wider cupolas than in narrow ones, and greater economy must result. The only practicable means of preventing this loss—lagging the cupola is out of the question—is by circulating the air blast round the cupola and carrying the heat thus taken up back into the cupola, so that so far as the portion of the cupola treated is concerned the loss of heat is avoided. Obviously, any cooling of the metal reservoir is out of the question, as the circulation of air round it would remove heat more rapidly than it would be dissipated by ordinary radiation. Clearly, also, the largest loss will occur in the hottest part of the furnace—the melting zone and immediately below it. Incidentally, any cooling that may be effected will tend to protect the lining of this most important part of the furnace and maintain the lines of the furnace interior.

Several makers of furnaces, either designedly or from convenience of blast supply, circulate the air round the furnace—the ordinary outside air belt, as used in the Thwaites "Rapid," Allday & Onions, and Collian & Whiting cupolas. Numerous others may be mentioned. The air at the tuyere is considerably hotter than the atmosphere. In some cupolas the air belt is constructed inside the casing, thus reducing the thickness of the lining and increasing the heating effect. The "Jumbo" furnace and the "Calumet" may be cited as instances. Reference may also be here made to casings placed in the upper part of the furnace, avowedly for the purpose of heating the air blast, as in Hyham's cupola. To avoid undue importance being attached to this point, the value of the saving effected may be stated in terms.

A hundredweight of coke containing 90 per cent. carbon requires approximately 15,000 cub. ft. of air at the ordinary pressure for its complete combustion, allowing for no excess, equal to 12 times its own weight. This is assuming its conversion to CO_2 (and would produce the same volume of gas with a weight equal to 13 times that of the carbon burnt). This, if heated 1° Fah., would contain 328 B.T.U., or if heated 100° Fah. 32,800 B.T.U., less heat than would be generated by the complete combustion of 2·5lbs. of the coke. Its effect on the working of the cupola, however, is greater than the smallness of the amount would imply. The chilling effect of the air as it enters the cupola is reduced, and there is less tendency to form obstructions. A better distribution is consequently assured.

There is little probability of the gases emerging from an ordinary cupola being cooled below 500° Fah., and they usually reach 650° to 700° or even higher. It follows that at the former figure the loss from this cause, as shown above, would be equal to a little less than 13·5lbs. of coke, or 12 per cent. of the weight of coke burnt, calculated on the burning of the carbon to carbon dioxide. If calculated on carbon monoxide the percentage is nearly 18, owing to the smaller amount of heat generated, although the weight of gases is only a little more than half ($\frac{7}{13}$) for the same weight of fuel burnt. If two-thirds of the carbon burns to CO_2 and one-third to CO, the loss is approximately 14 per cent. The actual loss in many cases is more than double this amount, as the temperature of the escaping gases is often 1,000° Fah., or even higher, and the proportion of CO greater. Further the quantity of air supplied is in excess. The present figures are based on the minimum quantity. Any modification that will cause a reduction in the temperature of the escaping gases and in their amount will tend to economical working.

Since the initial temperature of the gases is fixed by the temperature of melting required for teeming purposes, it follows that this will depend on the extent of the subsequent cooling. In this connection the amount of the gases as well as the temperature must be considered. Since gases only give up their heat by contact with solids, and the rate of exchange is proportional to the difference of temperature between the bodies in contact, in a cupola of any given capacity the smaller the amount of gas to be dealt with the greater the extent to which its temperature will be lowered. Obviously, all air that enters the cupola at any point must be actually burnt.

As pointed out, carbon in burning to the monoxide generates less than a third of the total heat of combustion. The loss of heat due to this cause is obvious. Its presence may be due to an insufficient air supply; bad distribution owing to certain areas of the furnace not receiving their proper quota while others receive an excess; cooling down of the carbon monoxide thus generated below the ignition point before it is mixed with the air intended to produce complete combustion. In any case, to generate the heat necessary to carry on the melting, an increased amount of coke must be burnt. So far attention has been devoted solely to the economical aspect, because if economy, represented by the useful application of the heat produced, be attained, the

accidental difficulties usually encountered will be minimised or disappear altogether.

The relation of the height to diameter will determine largely the number of contacts which the gases in the ascending current make with the solid matter of the charge, and thus the extent of the cooling effect it produces. All the heat abstracted will be carried downwards towards the melting zone and reduce the amount it will have to take up in that region, so that not only economy will be secured but the time occupied in absorbing it will be less; the melting will be quicker and the metal will be exposed for a shorter time to the action of the blast, with consequent less alteration in the calculated composition of the metal

In comparing narrow and tall structures with others wider and lower it must be noted that for the same volumes of gases and weights of charge the velocity of the gas current in the narrower furnace reduces the time of each individual contact but increases the number. In the wider, the time of contact is increased, but the number is reduced. That the former condition is most efficient will be seen when it is remembered that gases are the worst conductors of heat, and when contact occurs the film in immediate contact has its temperature lowered by giving up heat, and that the heat from the remainder of the gas can only be transmitted through the cooled film, thus slowing down the rate of transference. It is due to this very largely that even when burning larger amounts of fuel the old-fashioned low cupolas do not produce metal as hot and fluid enough for the lightest type of castings. In some of the old cupolas, with a total height of 7ft. to 8ft., and tuyeres 22in. to 26in. above the bottom, the top of the bed frequently extended 15in. to 18in. above the tuyeres, and thus left only 3ft. to 4ft. for the reception of the charge.

In modern cupolas a ratio of height to diameter of about 5 to 1 gives satisfactory results, as affording the greatest economy, without unduly increasing costs of construction and handling of stock. A further point is the possibility of the lodgment of the charge, especially in small cupolas, and the necessity of using bars to dislodge it. If the obstruction is low down the difficulty of removal becomes too great if the charging hole is high. A ratio of 4 to 1 is often maintained on this account. The efficient concentration of the heat will operate in every direction; less fuel burnt means also less air necessary, and less power for blowing purposes and most regular working of the furnace.

The rate at which the fuel is burnt and heat generated, which determines the melting rate in the cupola, is dependent on the quantity of air supplied in an efficient manner. In the older cupolas the tuyere area was far too small, and very curious conclusions were frequently arrived at. An increase of pressure produced better results. This was ascribed to the necessity of securing penetration of the charge by the blast, whereas its effect was mainly due to the increased amount of air so supplied, as well as its greater penetration. It will be seen that if a tuyere opening into the larger chamber of a cupola is incapable of supplying sufficient air to extend over its superficial area its upward movement will commence near the sides of the chamber, leaving the middle unaffected; but with a larger volume its effect will penetrate more deeply into the mass, the resistance offered to its lateral as compared with its vertical movement determining its relative movement in the two directions. An increase in pressure will, by driving it forward, overcome the natural tendency of the air to rise, due to becoming heated, and the less close packing of the material in contact with the furnace wall. The best results must ensue when an equal quantity of gas is diffused over the whole sectional area of the furnace and rising regularly through the stock in the furnace. Any tendency of the air to creep up the sides in large volumes will, unless the bed is deep, produce cooling and a tendency to hanging of the charge.

It follows, since a definite amount of air is required to burn coke used in melting, that for the admission of a given quantity of air at a given pressure, a certain tuyere area is necessary; that the minimum pressure necessary to secure the uniform diffusion of the gases will vary with the diameter of the furnace; and the rate of supply must vary with the depth of the stock above the tuyeres, since that will determine the frequency and period of contact From the latter conclusion it would appear that for every cupola, in order to get the most economical results, there would be a different ratio, but if the height is sufficient to secure the cooling of the gases, a further increase has little or no effect unless it is such as to materially increase the resistance offered to the free passage of the gases through the contents of the furnace It may, therefore, be eliminated and its application limited to those older and lower furnaces now rapidly disappearing

The consideration, however, affords thought on the value of adjustable tuyere areas such as are provided by reducing tuyeres or even by cupolas having upper rows provided with doors for closing them when necessary. The provision of adjustable tuyeres is of advantage on experimental cupolas or on those dealing with material liable to great fluctuations in size and tendency to pack in the cupola, or where great fluctuations in the blower are likely to occur through lack of power, &c.; but on those running on uniform material under constant conditions adjustable tuyeres afford no advantages other than those of emergency. The other factor controlling tuyere area is the shape. The volume passed by tuyeres of equal area, but of different shapes, will vary with the friction encountered, and as $pa = KSv^2$, where p = pressure, a = area in square feet, S = area of surface, v = velocity, and K = coefficient of friction. It follows that the friction will vary with the size of bounding surface, whether round, square, triangular, or flat, and an increase in area in these proportions will be necessary in passing from one form to another if equal amounts of air are to be delivered under the same conditions of pressure.

The results of experiments carried out to determine the best ratio of tuyere area to sectional area must consequently vary. Bellamy arrived at a ratio of $\frac{1}{1{\cdot}92}$. The following experimental results representing the conditions finally decided on may be compared:—

	No. 1.	No. 2
Diameter at tuyeres	32·5 in.	47·0 in.
Diameter, widest part	40·0 ,,	61·0 ,,
Diameter of tuyeres	4·5 ,,	5·25 ,,
No. of tuyeres...	3 ,,	4 ,,
Height tuyeres to stage	96 ,,	84 ,,
Height bottom to tuyeres	28 ,,	28 ,,
Blast pressure...	20 ,,	30 ,,
Sectional area of tuyeres	17·4 ,,	20 ,,
Tuyere area	1 ,,	1 ,,
Volume of air per square inch per second	1·2	1·44
Area fed per square inch tuyere area ...	11.5	14

The smaller cupola was melting from 2·5 to 3 tons per hour and the larger 5 tons, with a coke consumption (without bed charge) of 1 to 7. Under the conditions of working this was good. It will be observed that the average of the sectional areas of the two, viz., 18·7, compares favourably with the former determination. Neither of the cupolas was as high as it would be advisable to make them if new ones were being installed, and in that case probably a nearer approach to the figures might have been made.

In existing cupolas the throttling of the blast by tuyeres too small for the purpose is often a source of delay and loss. On the other hand, too large a tuyere reduces the blast pressure below the limit of efficiency.

Few points in connection with cupola construction have received more attention in recent years Each inventor has endeavoured to secure the most perfect distribution and complete combustion. Apart from the question of pressure, the position of the tuyeres exerts a great influence and the advantage of using a number of tuyeres is so fully recognised as to require no comment. Special shapes may be divided and classified as elongated deep tuyeres, flat tuyeres or a combination of the two. The reducing tuyeres of the Truesdale and Laurence type, as well as vertical slot tuyeres, belong to the first class. In the second class, sheet blast, oval, expanded, Blakeney, MacKenzie, Whiting, and many others

are included, while the triangular, reversed T, and the horizontal and vertical slot combination belong to the third class. Some of these, like the Blakeney, are intended to give certain directions—more or less important to the blast—but it is first necessary to consider them as mere air inlets.

In tuyeres of the first and third types, the objects aimed at were to supply air in such a manner as to secure complete combustion and to prevent bridging of the furnace, the upward extension of the tuyere being intended to supply air to consume the CO generated by the air entering by the lower portion, which in many cases was wider and supplied the bulk of the air. How far this is possible is very doubtful. The conditions previously considered will show that at the ignition point of carbon monoxide, coke itself would burn in a supply of air, and the heat produced by the carbon monoxide burning would increase the temperature, thus making it burn more readily. Further, the upward extension of the tuyere—some of them were 12in. high, and in a few cases 16in. to 20in. high—would mean an extension of the coke bed above that level and correspondingly higher position of the melting zone, with a reduction in the effective depth of descending charge cooling the gases. The successful results obtained by some of these arrangements must be attributed to a better supply of air and the greater number of tuyeres, giving a better horizontal distribution of blast, rather than to their upward extension.

The advantage of flat tuyeres lies in the fact that to secure an adequate tuyere area they must extend round a greater part of the circumference and secure a better and more even distribution of air. The nearer they approach to a continuous slot the more perfect this becomes. The consequent narrowing of the aperture brings the zone of active combustion and the melting zone lower in the furnace, thus tending to economy. Whether any specialised form has distinct advantages will depend on the blast pressure. An expanded tuyere widening towards the furnace could only be effectively used with a higher blast pressure than would be required by a straight slot or by one which is contracted towards the interior of the furnace.

Lowering the position of the tuyeres and diminishing the thickness of the coke bed increases the effective height of the cupola and tends to economy. The height of the tuyeres, as the main factor in determining the position of the melting zone, has also a marked influence on the practical working of the cupola, such as its freedom from hanging and bridging. Other factors that enter into the consideration are the pressure and volume of blast, as they affect the amount and upward velocity of the air current. Increased quantities absorb more heat from the material immediately in front of the tuyere and produce a greater cooling effect. Whether this causes the hottest zone to be somewhat raised or not will be influenced by the actual amount blown in. If this exceeds the required amount or the amount that can be usefully employed in combustion under the working conditions the zone will be raised, but if the increase does not exceed this quantity then the amount of fuel usefully burnt in the region of the tuyere will be increased, the amount of heat generated greater, more rapid melting of the stock, accompanied by a quicker descent of the charge, with a corresponding greater cooling effect on the gases, and greater concentration of heat in the melting zone with the lowering of the region. There is, therefore, considerable justification for the provision in cupolas of means of adjustment of the tuyere position to suit all the exigencies of any particular case, but once that position has been found, unless some departure is made from the existing conditions, there does not appear to be any further reason.

In actual working, pressure and volume of air should be maintained as nearly constant as possible and the shape of the furnace should not be altered or its capacity increased or diminished by changing the thickness of the linings, as sometimes advocated, nor should the daubing up of the walls be so carried out as to alter the diameter by giving a smaller diameter at the beginning of its use to allow of greater wear and tear before daubing up again—a variation sometimes amounting to 4in. Such a variation on a 30in. cupola means an increase of 15 per cent. on the sectional area of the cupola.

The distribution of the tuyeres round the cupola includes the consideration of the employment of one or more rows. From the consideration laid down at the commencement, the following deductions may be made. Since the concentration of the heat low down in the furnace gives better facilities for cooling the gases, and this can be best effected by placing the tuyeres low down, if it be possible to supply a sufficient amount of air and properly distribute it by a single row of tuyeres, the best results, economical and practical, will be secured. But where a greater amount than can be properly distributed by a single row is employed, in order to secure rapid melting, two or more rows may yield better results. The advantage, if any, that is secured results from increasing the *volume of the furnace* in which active combustion is proceeding, and necessitates increasing the depth of the coke bed to compensate for a raising of the level of the combustion zone. The extent to which it is effective or otherwise will depend on the character and disposition of the coke in front of the tuyeres. If the bed be more readily penetrated, distribution will be easy and a single row of tuyeres effective. When a double or triple row of tuyeres is used, the disadvantages alluded to above may be minimised by giving the upper rows such a downward inclination as will cause a concentration of the blast on a lower plane. How far this will be effective is influenced by the pressure and by the fuel, for it must be remembered that the penetration and distribution are not such as would obtain in an empty furnace.

It will be inferred from the foregoing that where more than one row of tuyeres is necessary, the distance between the rows should be as short as possible. Upper rows of tuyeres are sometimes a source of trouble. If a lump of cold iron gets in front, bridging may quickly commence, and from the position of such tuyeres it is obviously more likely to occur, especially when the minimum coke charges are being employed. Hence the provision made in many cases of doors or dampers to the top tuyeres, at least, and the permanent closing of them by many foundrymen. One advantage of a double row of tuyeres is that it provides the foundryman with a cupola having some reserve in its melting powers. A cupola of adequate diameter with adjustable tuyeres and an additional upper row which may be closed at will, may be used as a single-row furnace, with a thick lining for general purposes, but on occasion the increased thickness of lining may be removed and the additional tuyeres called upon. This would necessitate the existence of sufficient blowing facilities to meet the increased demand for greater volumes and pressures.

Consideration of the internal shape of the furnace will be restricted to the internal lines, and the question of drop bottoms and other points mainly connected with facility of handling will be omitted except where they have a definite bearing on the efficiency of working. All makes of cupola may on this consideration be classed under three headings: (1) Straight-shaft cupolas, with or without enlarged bottom reservoirs. (2) Cupolas contracted in the region of the tuyeres, (*a*) with straight shafts, (*b*) expanded shafts. (3) Cupolas with shafts tapering upwards.

The advantages or otherwise of these forms must be looked at from two points of view. Ease in handling, as well as economy, is important, and the shape probably exerts a greater influence on this than on the economy of melting. Bearing in mind the modern method of charging and working a cupola, viz., the charging of the fuel and metal in distinct layers so adjusted that the top of the bed coincides with the top of the melting zone, as indicated, the effect produced on the lining and the charges so adjust that as the last portion of a charge melts at the level of the lowest point of the melting zone and the next layer of coke sinking just fills the zone so that the next charge of metal begins to melt at the top of the melting zone, it will be seen that success and regular working depend on the uniform descent of the materials, and if uniform distribution of blast be secured a straight wall would ensure this.

Any tendency of the blast to pass up the sides of the furnace as the result of the looser packing of the material in contact with it would lead to greater cooling immediately above the tuyeres, although a greater amount of combustion

might result at a higher point in virtue of the increased amount of air traversing that part of the furnace. In that event the melting zone would be raised at the sides and lowered in the centre of the furnace, while the gases at the sides would be less efficiently cooled and the metal would not be preheated to the same extent. A slight increase in the thickness of the fuel layer at the sides, so as to provide a somewhat larger amount to correspond with the increased quantity of air, would prevent it from burning away too rapidly and permitting the unmelted metal or slag to come down so far as to meet the cooling effect of the blast and getting in front of the tuyeres, thus setting up bridging. The practice often followed of heaping the metal to a greater extent in the centre of the furnace provides this disposition of the materials, and no obstruction is offered to the regular descent of the charges.

In cupolas contracted in the region of the tuyeres, the object of getting the blast to the centre of the cupola, often given as the ostensible reason for doing it, is fulfilled; but, as previously shown, this can be effected by properly adjusting the blast pressure to the diameter of the furnace, and any real advantage must be looked for in another direction. Since the value of any contraction, except possibly in cupolas of the largest size, in supporting the weight of the contents may be passed over as unimportant, the only benefit possible would be that derived from securing a better distribution of the hot gases from the combustion region among the stock in the upper part of the furnace. It undoubtedly does this by delivering the gases into the centre of the furnace and preventing them escaping up the sides. The early success of Ireland's cupola must be, in the author's opinion, attributed to both these causes. It must be remembered, however, that such narrowing of the cupola is practically reducing the cupola to one of the narrower dimensions, as all combustion and melting must be done in the contracted area.

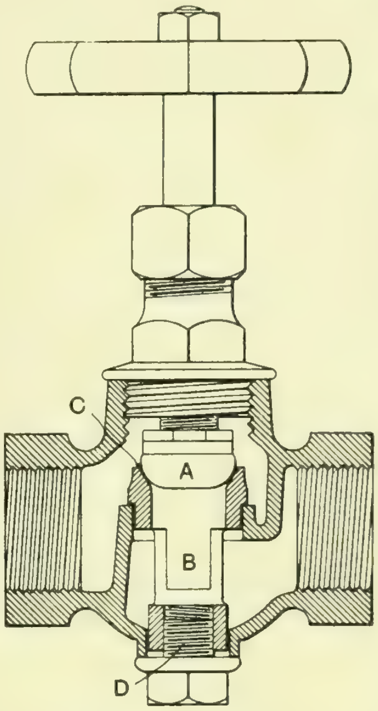
Further, any contraction that is made must extend above the uppermost limit of the melting zone or the obstruction it offers (especially in those having no slope but simply built out in the brickwork) would be likely to lead to bridging by the melting material forming accretions whenever a slight or momentary cooling takes place. How far this is liable to occur will be familiar to those who have studied the effects of the lining getting out of shape; and the statement made by Kirk that in his experience with the MacKenzie cupola that "slag and cinder adhere to the lining over the tuyeres and become very hard and difficult to remove, and if care be not taken to remove them after every heat it soon builds out, which reduces the melting capacity and increases the tendency to bridge and hang up."

In cupolas with shafts tapering upwards a further condition is involved. That the descent of the material is assured is palpable, but the contraction appreciable would have the effect of permitting the hot gases to come into more direct contact with the sides of the upper part and produce a greater heating effect. This, however, would in most cases be slight. The author is acquainted with only one cupola in which this is carried into practice—the water-jacketed cupola of Gruelin—in which the radius increases by the thickness of the plates at each joint from the top downwards. In this cupola the effect of the greater heating of the sides cannot be gauged, as the circulating water prevents any undue heating. As stated previously, the consideration of drop bottoms, receivers, and other special arrangements was not included in the matters it was the author's intention to discuss.

New Mineral Engines for the Midland.—A new series of 2—8—0 type superheated mineral locomotives, designed by Mr. Henry Fowler, chief mechanical engineer of the Midland Railway Company, have been constructed at the Derby works. They are intended for hauling heavy mineral traffic on the Somerset and Dorset Joint Railway. The new engines have been designed to deal with loads 50 per cent. heavier than those previously hauled over the steep grades of the line.

FOSTER'S STOP VALVE.

We illustrate herewith a design of stop valve more particularly intended for use with high-pressure steam, the invention of Mr. W. H. Foster, of Messrs. Edward Foster & Son, Ltd., of Central Brass Works, Woolshops, Halifax. It is claimed for this design that the detrimental cutting action of the steam on the seating is avoided, and that equal expansion and contraction of the seating is attained, thus tending to prolong the life of the valve. The valve casing at its upper part is provided with a stuffing box through which works a screwed spindle carrying at its lower end a disc valve A having a partly spherical or curved face, the valve disc being free to rotate around and capable of a slight swivelling movement on the spindle to enable it to bed itself truly. In conjunction with the valve disc there is employed a hollow plug B forming a removable seating. This plug comprises two rings, a lower one and an upper one, connected by vertical arms, with openings between them to permit of the passage of steam through the plug. The lower end of the plug is adapted to fit loosely in an opening in the bottom of the casing, a flanged set-screw D engaging in a screwed opening in the bottom of the plug and serving to hold the plug in position. The upper part of the plug has an annular shoulder which is adapted to rest upon an annulus surrounding an opening in the dividing wall of the casing, the plug being a loose fit in such opening. The plug extends a suitable distance above the shoulder, and its upper end is coned out internally as at C to an angle of approximately 60°. This cone forms the seating for the valve disc A. Since the plug is a loose fit in the casing, and since the internally-coned portion C forming the seat is located at a point some distance above the shoulder which supports the plug in the casing, unequal expansion or contraction of the casing is not transmitted to the seat, which always retains its true form and enables the valve to make a tight joint, whilst the formation of the seat is such that it is not affected by any cutting action of the steam as it passes through the valve. Removal of the set-screw D at the bottom of the plug enables the latter to be withdrawn through the stuffing-box opening in the top of the casing, no special tools being required, as the loose fit of the plug always permits of its being lifted straight out.



Foster's Stop Valve.

BUILT-UP HIGH-SPEED CUTTING TOOLS.

A process of welding high-speed to low-carbon steel (0·25 to 0·60 per cent. carbon) has, according to "The Iron Age," been developed by Mr. Adolph Rosner, of Bridgeport, Conn., U.S.A. The high-speed steel piece is not dovetailed in, nor brazed, but welded against the flat surface of the low-carbon steel base, to make one solid piece. Any kind or make of high-speed steel can, Mr. Rosner states, be welded successfully. The accompanying illustrations show the construction of the tools, from which it will be seen that a small piece of high-speed steel for the cutting edge is welded to a low-carbon steel base, called the shank. The two pieces to be welded are heated in a gas furnace. The high-speed steel is heated slowly to welding heat, over 2,000° Fah. The pieces are taken

out of the furnace and put under pressure to unite the two metals. This takes only a few seconds. A special flux is used in welding. It has been found that the quicker the temperature is brought from hardening temperature down to about 1,300° Fah. the better the cutting quality of the tool. The hardening of the tool takes place at the same time and with

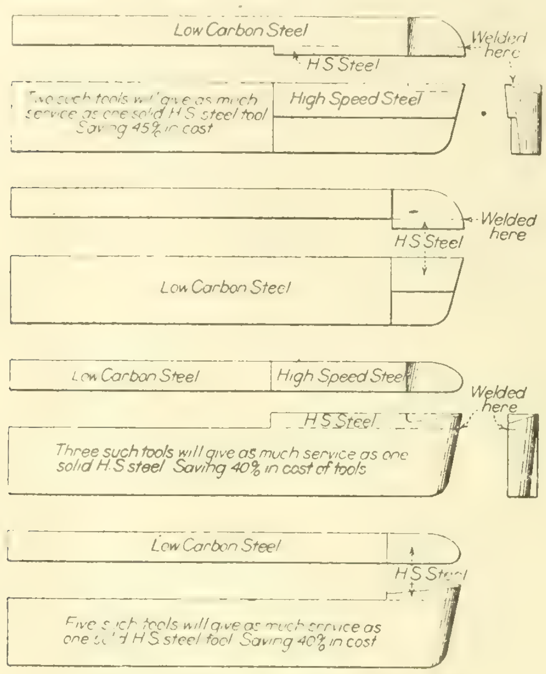


FIG. 1. BUILT-UP LATHE OR PLANING TOOLS.

the same heat as the welding. Right after welding the tools are ready to be ground and used. Welded forming tools, dies, punches, milling cutters, taps, knives, &c., have to be annealed after welding to make machining possible, and after machining are hardened in the regular way, as with tools made of high-speed steel alone. Tools made in the way described are supplied ready for immediate use without reforging. When the

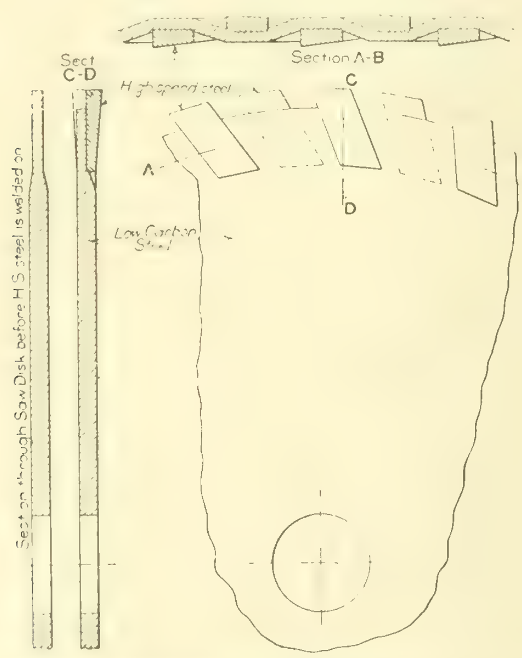


FIG. 2. CIRCULAR METAL SAW WITH HIGH-SPEED STEEL CUTTERS WELDED TO LOW-CARBON STEEL DISC.

cutting edge is worn out another piece of high speed steel may be welded on to the left-over shank. The tools can, of course, be annealed, machined, or re-hardened, as desired. It is stated also that it is possible to bend or forge such tools at the weld to a certain extent, if done at high temperature. With regard to the low-carbon steel shank, it is held that as the low carbon steel is such that it will stiffen by quenching in water, it is suitable even for long overhanging tools.

BY-PRODUCTS OF STEEL MANUFACTURE.*

BY ADOLPHE GREINER, D.SC.

I PROPOSE to direct attention to a subject that has greatly preoccupied my mind during the last few years, and the importance of which increases continuously; the subject of the by-products of the manufacture of steel. So much work has been done within the last few years on this question that I cannot claim to add any new thing to your knowledge thereof. I think, however, that it will not be without interest to collate the results obtained in this field, which is now being more and more cultivated. There is now, so to speak, hardly a single works of importance that does not consist of several departments closely linked together in interest and subject to a common control. Coke ovens, blastfurnaces, steelworks, with converters or open-hearth furnaces, rolling mills, and forges, constitute a harmonious whole to which all the parts contribute their co-operation in order to effect the greatest possible economy in working.

RETORT COKE OVENS.

Whatever system of coke ovens is employed, the essential condition is, of course, the production of a coke of the very best quality, as the blastfurnace will not submit to the use of an inferior fuel, irregular, half-coked, varying in hardness, in porosity, or in density, and everyone who has had the management of blastfurnaces well knows that there is no falser economy than to employ an inferior coke. But since 1880 progress has been made, and from any of the modern coke ovens coke of the requisite quality may be expected and obtained. Let us now consider what secondary products may be obtained from coke ovens.

1. *Coke-oven Gas.*—This gas, which is exceedingly rich in calories (3,700 to 4,000 per cubic metre) was formerly used almost exclusively in heating the coke ovens themselves, being carried away by flues beneath the bottoms of the retorts or between the walls, and burned with the aid of unheated air admitted through openings on the outside. The burnt gas passed under boilers, where it served to produce fairly approximately the amount of steam required for the ovens and for the manufacture of sulphate.

It is somewhat astonishing that so many years should have passed before the advantages of burning the gases by heated air should have been taken into consideration. The application of Siemens regenerators would appear to have been plainly foreshadowed; it is possible that manufacturers shrank from the expense, otherwise regenerative ovens would have been introduced long ago. Thanks to regeneration, 50 per cent. of the gas is, as a matter of fact, saved, and it is permissible to say that the saving will not stop at this, and that the important heat losses, due to charging the coal and to the discharging and quenching of the coke will also be reduced. Besides this, it is found on studying the heat balance-sheet of the working of a coke oven, that the calorific energy absorbed by the distillation proper of the coal is of very little importance as compared with the heat losses of every other description.

On the other hand, if the process of the distillation of coal and of the heating of the walls and hearths of the furnace had been more accurately reasoned out, it would almost certainly have been recognised that the gas from coke ovens is of far too rich a quality to be employed for such purposes, and that it would be much better to reserve it for other metallurgical uses and to substitute for it a gas of poorer quality, yet sufficiently rich to produce the desired calorific effect. It should also be noted that coke-oven gas, which is rich in methane, can only be employed in the cold state, as some of its most valuable elements of combustion are decomposed by heat. Table I. shows the average composition and heat values of the three gases most frequently employed in the industry.

These data, which vary at different works, are those obtained in the laboratory at Seraing. Now both experience and calculation show that the temperature of combustion of a mixture of producer gas and air heated to 900° reaches 1,980° C., which is practically equal to the temperature of combustion of a mixture of cold coke-oven gas with air heated to 600°, which reaches a temperature of 1,940° C. A mixture

* Abstract of presidential address delivered to the Iron and Steel Institute, May 7th, 1914.

of blastfurnace gas and air, both heated to 900°, yields a temperature of 1,920° C. It follows, therefore, that if the gas from producers or from blastfurnaces can be obtained cheaply, it is highly advantageous to use them for heating the coke ovens, and to reserve the richer coke-oven gas for other metallurgical uses.

TABLE I.—*Average Composition and Heat Value of Gases.*

	Coke-oven gas.	Producer gas.	Blastfurnace gas.
Hydrogen	57	12	3
Carbon monoxide	6	19	26
Carbon dioxide	2	8	11
Methane	23	2	0
Nitrogen	12	59	60
	100	100	100
Calories per cubic metre	3·761	1·068	0·873

With regard to the value of these different gases, it should be viewed in proportion to their calorific power and in comparison with the value of the fuel for which these gases may be substituted. This depends, therefore, on local conditions, and on the nature of the use made of the gases. In the particular instance of the Cockerill Works, at Seraing, which are under my control, the following values (in pence per cubic metre) have been arrived at:—Coke-oven gas (in open-hearth furnaces), 0·15; coke-oven gas (for power purposes), 0·12; purified producer gas, 0·7; washed blastfurnace gas, 0·3.

2. *Tar, Ammonium Sulphate, and Benzol.* Some of the members here present can doubtless recall the chilling reception accorded on the occasion of the meeting in 1880 to the paper by Mr. Henry Simon, on the Carves ovens at the Bessèges Works, of the Terre-Noire Company, in France. This pioneer attack on bee-hive ovens achieved but a slender technical success in spite of the warm discussions which found echo in the "Journal of the Iron and Steel Institute," and it was not until 1898 that Mr. Darby, on the initiative of the President (Mr. Edward P. Martin), re-opened the question of the by-products of coke ovens. It is interesting to peruse once again the polite, but guarded, and mistrustful interest manifested in the results obtained at Brymbo and elsewhere. Further, the only by-products described by the author were the tar, the ammonium sulphate, and the steam.

There exist at the present day numerous systems of coke ovens—the Semet-Solvay, the Coppée, the Collin, the Koppers, the Otto, and others which pour upon the market large quantities of by-products. From one ton of coke there is obtained from 25 kg. to 40 kg. (55lbs. to 85lbs.) of heterogeneous and viscid liquid tar, the commercial value of which constantly rises, and which is usually sent by the works to factories, where it is submitted to fractional distillation, to yield industrial oils of very varied composition. In default of petrol, the Diesel motor works well with these products, and may in the future become a large consumer; the aniline dye works are also an important outlet for some of these hydrocarbons, amongst which naphthalin is also included.

In the construction of roads a large quantity of tar is likewise employed, while what may become a fresh source of profit for the tar derivatives is the direct manufacture of pitch for the progressive industry of the briquetting of fuels. Nearly one-half of the tar treated is employed for this purpose. Within the last few years 80 to 90 per cent. of pitch, having a remarkably high agglutinative power and competing strongly with ordinary pitch, has been produced from the tar by a special process of oxidation. A works to carry out this process has been established near Liége, in Belgium.

In certain cases it is advantageous to use the tar as a combustible, with appropriate burners; it may even be used in metallurgical furnaces, as is done at the Gary works in the United States, where three Siemens-Martin furnaces of from 90 tons to 100 tons capacity, heated by tar, have been at work for some time. The total quantity of steel manufactured in these furnaces during the year 1913 is given at 94,110 tons, and the average per cast at 94·2 tons. The mean consumption of raw tar is 34·94 galls. per ton. The steel made in the tar-heated furnaces was shown to contain 14 per cent. less sulphur than that produced by the other furnaces of the same battery, while the output was increased by 10 per cent. as compared with the average of the whole group. After having been deprived of their tar, the gases deposit their ammonia in leaden troughs containing sulphuric acid; the ammonium sulphate thus formed represents a weight of 11 kg. to 13 kg. (24lbs. to 28lbs.) per ton of coke; the salt is perfectly white, provided that care is taken, by means of an ingenious arrangement, to prevent it being contaminated by the least trace of tar.

By means of new and highly interesting methods, the very sulphur of the coal itself is brought to combine with the ammonia. It would not appear, however, that finality has been reached in the methods introduced in certain works by Burckheiser and Feld, but it may be seen to what extent it is sought to derive profit from the whole of the elements contained in the coal, including those which contaminate it.

The ammonium sulphate is used chiefly as manure; its consumption continues to increase, and the 600,000 tons which were used in 1900 became 1,300,000 tons in 1912, and will exceed 1,500,000 tons in 1914. You are aware that new nitrogenous manures are produced in Germany, Italy, and particularly in Norway, by the direct fixation of the nitrogen of the air by means of electricity; but the competition of the cyanamides and of the nitrate of calcium obtained by these processes is not as yet to be feared. On the other hand, the production of natural Chilian nitrates, which amounts to 2,500,000 tons per annum, will not increase during the next few years, so that the ammonium sulphate from coke ovens has before it a future which is the more promising, inasmuch as the demand for nitrogenous manures will undoubtedly continue to increase.

Finally, benzol is another by-product of the manufacture of coke, which has numerous uses; it yields on distillation the petrol (benzine) of the automobilist, and is used also as a solvent for india-rubber. Six to seven kilogrammes (13lbs. to 15lbs.) are obtained per ton of coke.

Even after all this there remains, finally, the rich gas, the use of which in the early stages was restricted to gas engines like the blastfurnace gas, but its high calorific energy naturally predestines it to metallurgical uses in metal mixers, open-hearth furnaces, reheating furnaces, and similar employments. In these various applications the heating of the coke-oven gas is exceedingly simple; it is, of course, necessary to adjust the burners to the working hearth of the furnace, the dimensions of which are determined in accordance with the teachings of experience. There is no more difficulty in running such a furnace than there has been in the United States in running furnaces on natural gas. In 1912, the United States consumed 15,750 millions of cubic metres of natural gas of 7,000 calories, at an average price of 0·265d. per cubic metre, representing a total value of £16,680,000.

The amount of gas evolved by a ton of coal may be estimated at 300 cub. metres to 350 cub. metres (10,500 cub. ft. to 12,500 cub. ft.). After passing through the regenerators this gas contains only a little sulphur dioxide and sulphuretted hydrogen, which it is necessary to eliminate, particularly when the gas is used in gas engines. This purification is effected by making the gas pass through layers of iron oxide spread in the chambers. It is advisable likewise to install a gasometer, not only because it allows of the composition of the gas and of the pressure at which it is delivered to the furnaces (which is highly important, particularly for the successful working of open-hearth furnaces) being rendered uniform, but also for storage purposes during the period when the steel works are stopped, such as from Saturday to Monday or during public holidays. It may be imagined that these gasometers must always be of enormous capacity, and that their installation must be expensive, but their cost price would soon be redeemed by the advantages to be derived from the additional quantities of gas rendered available. For example, the gasometer at the Cockerill Company's works cost £20,000, and has a capacity of 50,000 cub. metres. Assuming that the open-hearth furnaces are working only 300 days per annum, it would serve for the collection as a minimum of $65 \times 50,000 = 3,250,000$ cub. metres of gas of the value of 0·15d. per cubic metre. The annual saving would therefore be at least £1,948.

Another use for coke-oven gas which is becoming current practice is the lighting of towns and works. Indeed the distillation of coal in the coke ovens differs in nowise from that of coal in a retort. The average lighting power of coke-oven

gas is, however, lower than that of ordinary lighting gas, but this defect can be rectified by the use of Auer burners, which turn to advantage the calorific power. In any case, in order to satisfy the conditions of proper lighting fractional distillation is employed.

During the coking of the coal the composition of the distilled gases varies from hour to hour; gases which contain the heavier hydrocarbons, and are driven off earliest, are separated from those which are more suitable for heating purposes. Two hydraulic mains with the requisite taps are employed. Enormous installations have been at work during the last few years in Westphalia under exceedingly severe specifications, which fix the calorific value at 5,000 calories and stipulate for guarantees of purity from ammonia, naphthalin, tar sulphur, water vapour, carbon monoxide, and carbon dioxide. Some towns, such as Barmen, receive their lighting gas through mains 50 kilometres in length from the generating works; this town consumes 17,000,000 cub. metres per annum, at a price varying from 0·3d. to 0·5d. per cubic metre, whereas town gas costs double.

In Belgium a number of coke works are preparing to light the towns, while the town gas works, when increasing their means of production, do so by the installation of coke-oven batteries rather than of retorts. In England there are several central gas works; amongst others, the works established some years ago by Mond, whose reputation is world-wide. In America a number of towns are at present lighted by coke-oven gas previously purified. Finally, there may be instanced as a possible application for coke-oven gas the direct manufacture of nitric acid by the process actually investigated by Prof. Häusser; also, it is being sought to obtain from these gases the hydrocarbons, the derivatives of which are found in indiarubber, and certain experiments undertaken in this direction permit of the foreshadowing of the manufacture of artificial rubber.

(To be continued.)

BURNING PULVERISED COAL IN METALLURGICAL FURNACES.

THE American Iron and Steel Manufacturing Co., Lebanon, Pa., is burning pulverised coal in over 100 metallurgical furnaces of various types. The fuel is pulverised so that over 80 per cent. will pass through a 200-mesh sieve. The burners feed from 40lbs. to 900lbs. of coal per hour, depending upon the amount of heat required. The coal is conveyed automatically from the car to the pile, from which it is taken by screw conveyers to the driers and pulverisers. Screw conveyers are also used for conveying the pulverised fuel to the various points of consumption. A tank or hopper of sufficient size to carry about 15 hours' supply of pulverised coal is attached to each of the furnaces. On several occasions the fuel has ignited in these hoppers. In such cases it is only necessary to stop the supply and to feed the burning coal into the furnace until the hopper is empty. There is no danger of explosion under these conditions. The fuel should be delivered to the puddling and heating furnaces at a low air pressure. From four to six ounces of blast pressure is used to deliver the coal through a small pipe to the large blast pipe, which in a heating furnace is from 10in. to 14in. diam. In 1907 the average quantity of unpulverised coal required to produce a ton of puddled bar was 2,052lbs; in 1908 it was 2,034lbs. Tests made in 1913 indicated that from 516lbs. to 570lbs. of pulverised coal are required for heating one ton of iron in the piling furnaces. The records of the company show that the cost of preparing pulverised coal in 1912 was slightly over 2s. 6d. per ton, including transmission through pipes to the furnaces. The experience of the company has been so satisfactory that it is now largely increasing its installation for burning powdered coal and is making arrangements to apply it to open-hearth steel furnaces without checker work.

Boiler Explosion.—The formal investigation ordered by the Board of Trade to be held in regard to the boiler explosion at the South Parade Pier, Southsea, is fixed for hearing in the Grand Jury Room, Town Hall, Portsmouth, Hampshire, on Tuesday, the 16th prox., at 11 a.m.

THE FLYING-MACHINE FROM AN ENGINEERING STANDPOINT.*

BY FREDERICK WILLIAM LANCHESTER, M.INST.C.E.

(Continued from page 491.)

(4) *Body Resistance.*—The body resistance, as already stated, varies approximately as the square of the velocity. It is therefore evident that, with a machine of given weight, since the flight resistance proper (the aerofoil resistance) is constant, the higher the flight-speed the more serious relatively does the question of body resistance become, and the design of the car and its accessories, such as alighting gear, &c., is a matter of increasing importance as the contemplated flight velocity becomes greater. The calculation of body resistance involves the computation of the resistance of each individual element, and in some cases allowance for the interference or influence of one element or portion of another. Thus in the computation of body resistance it is necessary

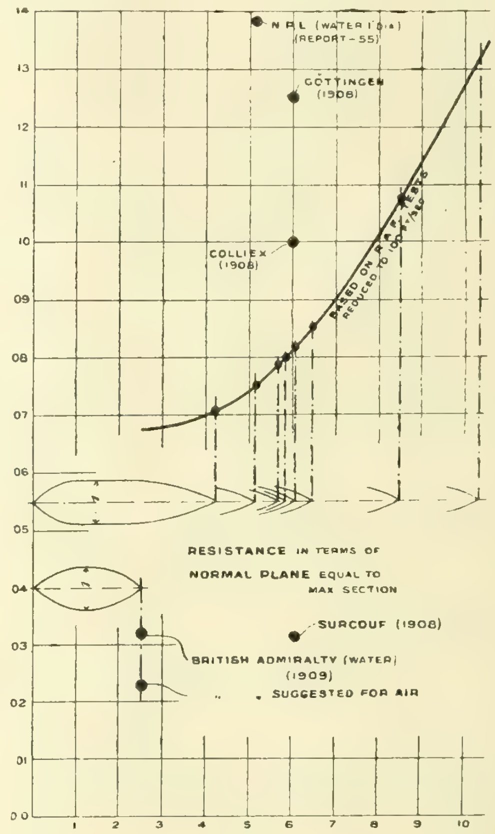


FIG. 20.

to have at command tabulated results of the resistance of spars of various sections, wires, wheels, and the like, in addition to a sufficiency of known data as to stream-line forms of various degrees of perfection. A considerable amount of experimental data has now been collected in this direction, but a great deal yet remains to be done.†

The resistance of the body-shape or fusillage is a factor on which at present the information available is the least satisfactory, since it is rarely possible for the designer to adopt a close approximation to a perfect stream-line form, or a form for which the resistance coefficient has been already determined; it is usually necessary to have recourse to model experiment in each individual case. This is no more than must be expected, in view of the fact that the same applies to the design of a ship's hull when any departure is made from existing practice.

A very few years since little or nothing was known as to the resistance of the so-called stream-line or ichthyoid body. In 1908-09 I made enquiries in the endeavour to obtain some figures on this subject. For bodies constituting a rough

* The "James Forrest" Lecture, 1914, delivered before the Institution of Civil Engineers, May 5th, 1914.

† For the resistance coefficients of spars, wires, &c., reference should be made to the various reports of the Advisory Committee for Aeronautics and the work of Mr. Eiffel and others, also section 9 following.

imitation of a good fish form, with ratio of length to diameter of about 6 to 1, the figures given in Table VIII. were supplied

TABLE VIII.

Authority.	Date.		Remarks.
Prandtl	1908	0·125	Given as approximate only.
Colliex	1908	0·100	From rough experiments at the factory of Voison Fréres.
Surcouf	1908	0·031	Given as an experimental determination by the late Col. Renard.
British Admiralty...	1909	0·032 0·023	Actual for water (ratio about Probable for air. [3 : 1).

by the different authorities named; the figures, given to me in various forms, are here reduced to represent the equivalent of normal plane in terms of the maximum cross-section.

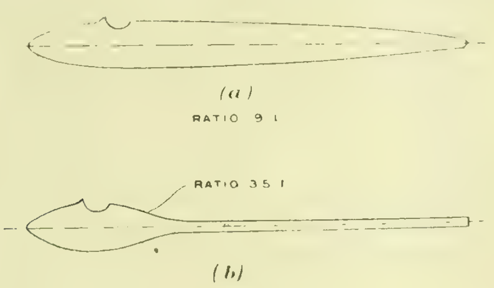


FIG. 21.

It would appear from more recent experiments carried out at the Royal Aircraft Factory, and at the National Physical Laboratory, that for a well-designed stream-line form the best result so far recorded is approximately 0·07, the coefficient of fineness length/diameter being round about the value 4 : 1.

The plotting given in Fig. 20 is based on a series of determinations made at the Royal Aircraft Factory, with corrections (for which I take responsibility) to compensate for the difference in the coefficient of skin-friction between the velocity, 20ft.-seconds, actually employed, and an assumed flight-speed of 70 miles an hour. The plotting represents the resistance coefficient for bodies of about 2ft. to 3ft. diam.

When we turn our attention to the design of the body of machines as they exist to-day, we find that although it is becoming customary to give the fusillage a distinct fish-like outline, it is rare that any real attempt is made to adopt a definitely stream-line or true ichthyoid form, such as employed for the experimental determinations already cited, and commonly used for dirigible balloons. It is not sufficient to give a rough general outline to the body if a material reduction in the resistance is required; it is necessary to go further than this, and to avoid as far as possible corners and projections of every description. In many cases in the body-forms used to-day the resistance is nearly as great as that of a normal plane equal to the mid-section area, and a body with a coefficient of less than 0·5, in view of current practice, must be regarded as exceptionally good. As a consequence the resistance of the fusillage and passengers alone is often equivalent to some 3 sq. ft. or 4 sq. ft., whereas an equivalent considerably less than 1 sq. ft. ought to suffice. It is not only necessary to avoid up-standing projections, such as wind-screens, &c., but even such things as longitudinal angles should be eliminated from the design; this latter point has been partially investigated by the National Physical Laboratory.

In the Paulhan-Tatin machine, mentioned in the researches of Mr. Eiffel, the question of body-form has been studied with extreme care, the form of body employed being substantially a solid of revolution, as given in Fig. 21A. The only irregularity in the fusillage is in the aperture for the pilot's body, which has clearly been reduced to the minimum possible. According to the results given in Fig. 20 it would be still better, from the point of view of resistance, to design the body on the lines shown in Fig. 21B, making the body only of sufficient length to contain the pilot, motor, &c., and carrying the tail organs from a tubular continuation. A model of this kind, made and tested at the N.P.L. (from designs of the Royal Aircraft Factory), gave a normal plane equivalent of about one-fifth of its maximum cross-section. The form was imperfect as a stream-line body, and the small scale ($\frac{1}{25}$ full size) otherwise rendered the resistance higher than it would be in actuality.—Advisory Committee Report 74, page 177.

It is evident that with sufficient experience the body fusillage resistance of an ordinary two-seat machine should be capable of reduction to the equivalent of 1 sq. ft. area of normal plane, since a good model of stream-line body of 5 sq. ft. maximum section should in itself offer less than half this resistance. Added to this we have the alighting chassis and auxiliary surfaces, the resistance of which should be capable of being designed for an equivalent of 2 sq. ft. if the design be studied in every detail, making 3 sq. ft. in all. On the basis of 80 miles an hour the resistance will then amount to 60lbs., or, say, approximately, 5 per cent. The body resistance in the machines of to-day is very much higher; it is commonly the equivalent of at least some 5 sq. ft. of normal plane: Mr. Eiffel gives 1 sq. metre (=10 sq. ft.) as usual.

(5) *Total Resistance.*—Fig. 22 represents graphically the position with which the designer has to cope; the horizontal line *a a* represents an aerofoil resistance coefficient of 7 per cent. The curve 2 represents (from *a a* as datum) the additional coefficient due to body resistance on the assumption that we are dealing with a machine of 1,200lbs. weight, in which the body resistance has the equivalent of 2 sq. ft. area of normal plane curve, 3 represents similarly the added body resistance on a basis of 3 sq. ft.; lines 4 and 5, 7 and 10, represent 4 sq. ft., 5 sq. ft., 7 sq. ft., and 10 sq. ft. respectively; curve 5 may be taken roughly to represent the best practice at the present time. It is evident that so long as flight-speeds were limited to 40 miles an hour or less, as was the case a few years ago, the body resistance remained a matter of minor importance; in fact, in the Wright machine, and in several other machines of that day, the pilot sat fully exposed, and little or no attempt was made to minimise resistance, whereas with speeds of 80 miles an hour the body resistance will, unless great care is taken in the design, considerably exceed the flight resistance proper. Fig. 22 does not represent the resistance of a given machine flown at different speeds, but rather the resistance of a series of machines

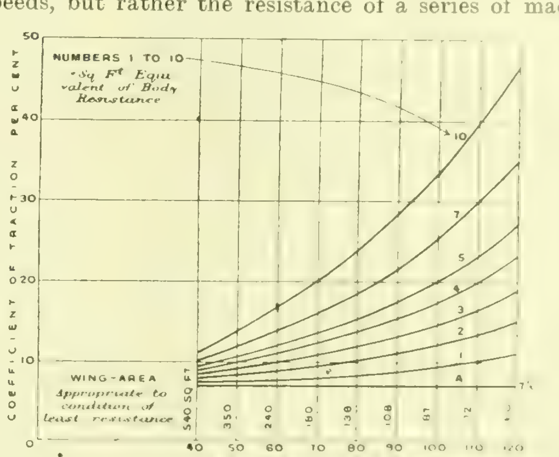


FIG. 22.

of given weight, *each designed for least resistance at its own particular speed*, and with body resistance equivalent to the area indicated.

Referring to Fig. 22, it will be seen that the total traction coefficient in the case of curve 5 at 80 miles an hour is roughly 15 per cent., the gliding angle consequently being 1 in 6·7: this is slightly better than the best figures actually obtained in the military trials of 1912. The highest speed at the military trials did not touch 70 miles an hour, so that on the basis given the gliding angle should have been better than stated; no allowance was made for the drag of the propeller, it is possible the difference is due to this factor.

The question of body resistance has for some time been a

matter of careful study by the staff of the Royal Aircraft Factory, and I understand that in some of the later models the equivalent normal plane area has been very considerably reduced. If we take an aerofoil coefficient of 7 per cent., and a curve representing 3 sq. ft. equivalent normal plane, we find that at 80 miles an hour the gliding angle, or the resistance coefficient, should be approximately 12 per cent.; or

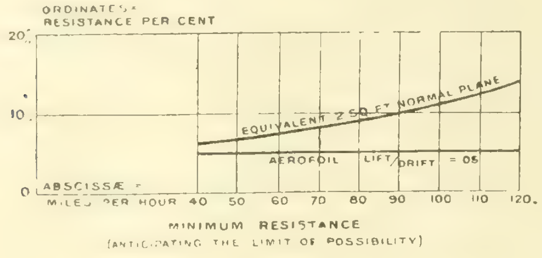


FIG. 23.

at 60 miles per hour 10 per cent.; I believe this figure to be in sight, though it may not yet have been actually reached.

As illustrating the extent to which the present-day results have been anticipated by theory, in 1907, dealing with the question of the power expended in flight, I tabulated the results of calculations for gliding angles as for complete machines ranging from 12° (approximately 1 in 5) to 6° (approximately 1 in 10). In the military trials of 1912 the worst gliding angle recorded was 1 in 5·3, and (as pointed out in the preceding paragraph) the present-day figure is gradually approaching 1 in 10.

If we try in the light of present data to look into the future it seems probable that the limiting gliding angle, or, rather, the minimum total coefficient of resistance may even be materially less than 1 in 10; thus, if it is found possible, in spite of structural difficulties, to obtain equal results in an actual machine to those obtained in wind channel model tests, viz., a coefficient of resistance for the aerofoil approximately to 5 per cent., and if the body area equivalent, for a machine of 1,200lbs. gross weight, can eventually be reduced to 2 sq. ft., a total coefficient of resistance as low as 8 per cent. may prove well within reach; whether the sacrifices necessary in order to achieve such results in practice would be justified the future alone can decide. The solution of any engineering problem is always to some degree a matter of compromise, and it would be rash to suggest that in the case of the flying-machine there are not considerations of sufficient importance to render it inadvisable to run after the last 1 per cent. reduction in tractive effort. A graph is given representing the coefficient of resistance on the basis of the present paragraph in Fig. 23. The aerofoil coefficient of traction is taken at 5 per cent., the weight of the machine as before assumed as 1,200lbs., and the suggested total of 8 per cent. corresponds to a flight speed of nearly 80 miles an hour.

Before we have finished with the question of resistance we need to know something as to the gradient of ascent, or climbing power required. A machine that is only capable of horizontal flight is evidently quite unserviceable; it is well understood, too, that any machine with an insufficient rate of ascent is intrinsically dangerous; not only does it remain too long at low altitude where any "fluke" in the wind is liable to bring about disaster, but in bad weather when buffeted about by the wind a pilot may find himself incapable of making altitude altogether if his initial margin of power is insufficient.

The rate of ascent for which provision has to be made depends very much upon the service for which the machine is required, for the ordinary needs of the aeronaut who wishes to make cross-country flights under fair-weather conditions, a margin of power representing an upgrade of 5 per cent. or 6 per cent. appears to be ample; there is probably no real advantage in any greater provision. For military or naval service, on the other hand, there are without doubt occasions when everything may depend upon the rapidity at which the machine can make altitude. I feel that I cannot do better than quote from the specifications given by the Superintendent of the Royal Aircraft Factory for two types of machine, viz., R.E. 1 reconnaissance aeroplane, and F.E. 3 gun-carrying aeroplane.* For the first of these the rate of climbing demanded is 600ft. per minute, or, taking the normal flight-speed at 70 miles per hour (the specification gives maximum 78 miles per hour, and minimum 48), we have a climbing gradient of approximately 10 per cent. For the gun-carrying machine the speed is given as 75 miles per hour, and the rate of climbing 350 feet per minute, which, expressed as climbing gradient, is a trifle less than 5½ per cent. Manifestly a machine carrying a gun of some kind (presumably a machine gun), and we may assume an adequate supply of ammunition, and perhaps a few square feet of bullet-proof armour plate, needs to sacrifice something in the matter of climbing power.

There is good reason to suppose that if a demand for higher speeds than those at present attained is in the future to be satisfied, success will depend to some extent upon our ability to build larger and heavier machines. By reference to Figs. 22 and 23 it will be seen how soon with increased fight-speeds the question of body resistance becomes a disproportionate factor; it is manifestly impossible in a machine of given size to reduce the equivalent normal plane area beyond a certain point, but it is evident that by increasing the weight and power of the machine the effect of such body resistances may be rendered less important since an increase in weight and power does not require a proportionately serious increase in the size of the members to which the body resistance is due. Also since the square of the product of l and V varies directly as the weight (where l represents the linear size of the aerofoil) the value of ξ is also a function of the weight and diminishes slightly as the weight is increased.†

(6) *Propulsion.*—We are now in a position to consider the question of propulsion. Whether we appeal to experience or theory it would appear that there is only one method of pro-

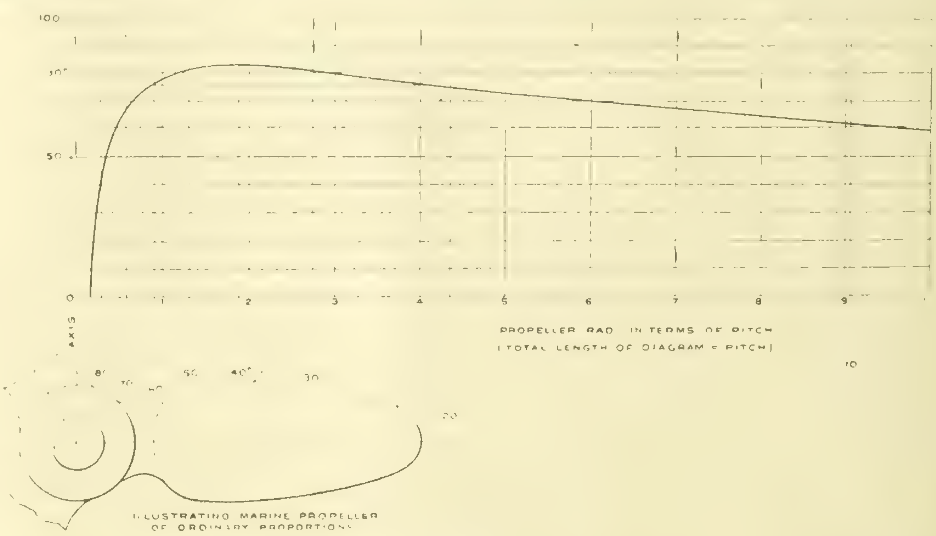


FIG. 24.

pulsion available, viz., the screw propeller.‡ The problem of propulsion, whether aeronautical or submarine, is essentially the same: the laws of dynamic similarity with certain reservations are strictly applicable. Roughly speaking, the conditions of usage of propellers in water and air may be compared by merely taking cognisance of the relative densities of the two

* Advisory Committee for Aeronautics, Report 1912-1913, p. 267.
† Compare Appendix I.
‡ Nature's method of propulsion wing flapping besides being very objectionable from a mechanical point of view, shows certainly no higher degree of mechanical efficiency than the screw propeller ("Engineering," February 26th, 1909).

media approximately 800 to 1. The laws of dynamic similarity indicate that this relation is not exact, but any refinement of theory on this score is of academic rather than of practical importance. Apart from fine points of this kind there is a limitation that renders the air propeller and the marine propeller not strictly comparable: this limitation is due to the appearance of the phenomenon known to the naval engineer as cavitation. The law of the relation of pressure to velocity for least resistance applies to the blade of the screw propeller precisely as it does to the aerofoil itself, so that if a propeller is being designed for least resistance the pressure per square foot at any point of the blade must bear its constant relation to the square of the velocity of the blade through the fluid at that point. In the case of the marine propeller this results in a speed being reached (at about 20 or 25 knots speed of vessel) at which the velocity of the blade tips is such that the negative pressure (on the back of the blade), based on the law of least resistance, is greater than the hydrostatic (absolute) pressure. Under these conditions a vacuum is formed in the vicinity of the blade extremity, and the system of flow is impaired; this is the condition of incipient cavitation, and as the speed is progressively increased the vacuum invades more and more of the blade area until the greater part of the propeller becomes ineffective. From the critical speed upward the design of the marine propeller becomes a compromise. The extremity of the blade is first designed broader to avoid developing pressures sufficient to initiate cavitation, and then, owing to the additional skin friction thereby involved, it is found desirable to adopt higher pitch/diameter ratio to prevent the extremities cutting the water with excessive velocity. Eventually the propeller for high-speed craft becomes one of extremely coarse pitch with blades of short or saucer-like form. No such thing as cavitation is experienced in the aeronautical propeller: if we should require to deal with propeller blade speeds approaching the velocity of sound we might find something analogous, due to the high rarefaction of air, but at present the aeronautical designer can afford to ignore all question of cavitation.

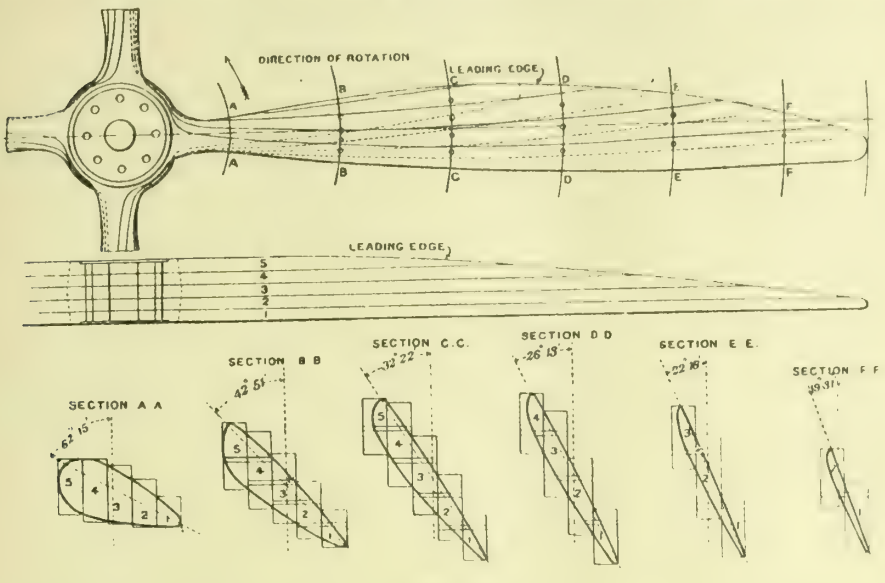


FIG. 25.

It is frequently stated that the theory of the screw propeller is entirely empirical and quite unsatisfactory: this is not my opinion. The theory of the screw propeller based on the theory of the aerofoil as laid down in my "Aerodynamics,"* appears to fully meet the requirements of the aeronautical designer. According to this theory the propeller blade is treated as an aerofoil, its P/V^2 ratio at every point of the blade is fixed by the same law as that of the aerofoil as given: following this the gliding angle of the propeller blade is constant from root to tip. The section of the blade is at every point designed as an aerofoil in which the true helical surface corresponds to the horizontal plane in flight.†

Under these circumstances it is shown in my work that each point of the propeller blade has efficiency proper to itself, and is represented by a curve as plotted in Fig. 24, which corresponds to a gliding angle of 6°, or approximately 10 per cent. Under these conditions it will be seen that in the region of maximum efficiency is just over 81 per cent. Unfortunately, we cannot use only the region of maximum efficiency: we have to employ the blade of considerable length, and consequently parts of the blade have an efficiency below the maximum. If we take a propeller of the usual proportion in which the pitch is about $1\frac{1}{4}$ times the diameter, that is, such a blade as represented in Fig. 21, we see that the marine engineer declines to employ any portion of the blade with an efficiency of less than about 97 per cent. of the maximum, that is to say, the efficiency of different points of the blade varies from 77·5 to 81 per cent., or theoretically the limit of efficiency of such a propeller should be round about 77 per cent. Unfortunately a propeller "in being" cannot consist of blades alone, it requires a boss and a connection between the boss and the blades, and in driving these functionally useless parts through the water a considerable further loss is inevitable. Probably it is for this reason that the actual efficiency of a marine propeller rarely exceeds 70 per cent. In my work a design is given of an aerial propeller based on theory alone, in which a very conservative estimate is taken of the gliding angle. If in the light of present knowledge we assume the propeller blades being of the aspect ratio corresponding to that of my 1894 gliding model, the gliding angle or resistance coefficient will be about 5 or 6 per cent., and we might anticipate a theoretical limit to the propeller efficiency of 88 or 90 per cent. We have here, as in the marine propeller, to provide a boss and arms, and we require to take into account the fact that it never pays in practice to take the full diameter of the propeller that theory would indicate (it is better to sacrifice a few per cent. efficiency to save weight and clearance diameter). Everything considered I am

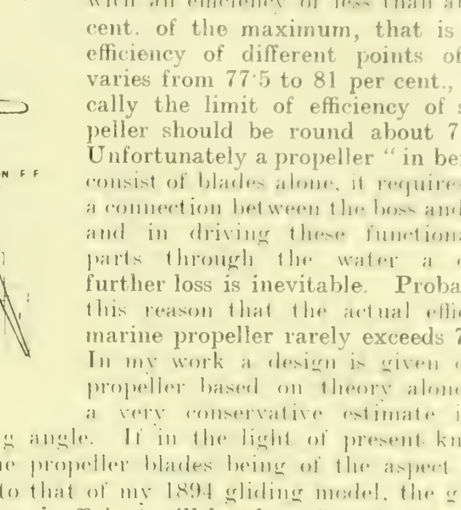


FIG. 26.

disposed to put a limit of efficiency of an aeronautical propeller at about 85 per cent.; this is higher than has been found possible in marine engineering.‡

* "Aerial Flight," vol. i. ch. ix.

† There is one factor which affects the analogy between the aerofoil and the propeller blade: the latter is not able to the same extent to hold or accumulate a dead-water wake, the propeller blade sheds its dead water continuously by centrifugal force. The extent to which this affects the problem has yet to be determined.

‡ There should be nothing to prevent the marine propeller at speeds below the cavitation point giving as high an efficiency as the aeronautical propeller were it not for the limit imposed by the strength of materials. To obtain the highest efficiency even in an air propeller it may be found necessary to abandon the wooden blade and substitute a solid nickel steel blade of somewhat the sectional form given in Fig. 18; this, in the case of an 8-foot propeller, would mean a blade 4ft. long, the outer 3ft. of which would be the effective blade, the maximum width in the widest part being no more than 3in. or 4in. If any attempt were made to design such a propeller for marine work, there is no material known at the present time that would stand the stress involved: the pressure-reaction, speed for speed, would be about 800 times greater in water than air, and the aspect ratio of the blade that can be utilised for marine work is strictly limited by this fact; even the softest of timber is relatively far stronger as a medium for the construction of an aeronautical propeller than any known material, even tempered tool steel, would be for marine work. In the design of an aeronautical propeller advantage may be taken of the fact that a very slight forward slope of the blades relieves the blades of all bending stresses, the resultant of the centrifugal force and pressure reaction is in the line of the blade, and the latter is consequently stressed in pure tension.

My method of propeller design has been adopted and employed for some years by the Superintendent and staff of the Royal Aircraft Factory with very satisfactory results; at present there is but little available information on the question of efficiency, owing to the fact that the arrangements at the disposal of the Royal Aircraft Factory do not permit of the testing of full-sized propellers.

Working drawings of a propeller, designed at the Royal Aircraft Factory by this method, are given in Figs. 25 and 26. For the full exposition of the system of "lay out," reference should be made to the work already referred to.

As an alternative and purely empirical basis of treatment, we may fall back on our experience in marine propulsion. There is a practical rule which appears to be commonly adhered to in the design of successful marine propeller for moderate speed sea-going craft. The area of the propeller disc is approximately 1 per cent. of the total wetted surface. This rule has been found by me to represent a rough average of the practice in various cases,* but whether it is an accepted rule or not I do not know. Let us take the case of a flying-machine involving, say, a thrust of 200lbs. at 80ft. per second; at this speed the frictional air resistance will be approximately 0·035lb. per square foot of surface (0·07lb. per square foot of lamina, *i.e.*, double surface); thus the resistance of the machine is approximately represented by 6,000 sq. ft. "wetted" surface, and, following the rule given in the case of water, the propeller disc should be 60 sq. ft.; this corresponds to a propeller diameter of about 9ft. In an actual machine of about this size the propeller is commonly of about 7ft. to 8ft. diam., which, taking everything into account, is in substantial agreement. The propeller employed in flight is of necessity (from considerations of the engine revolution speed) of finer pitch than that of best efficiency. Under these conditions theory shows that the correct diameter is less than that of the propeller of best diameter pitch ratio, such as employed by the naval architect.

There are (in the present state of the art) two prominent reasons for the adoption of a propeller for aeronautical machines of finer pitch than that of greatest efficiency; firstly, there is the question of suiting the pitch of the propeller to the running speed of the engine. For the power necessary in a modern aeroplane (from 50 h.p. to 100 h.p.) a stroke of about 5in. is found to design well in proportioning the engine; now it is uneconomical both from the point of view of weight saving and of petrol consumption to employ too low a piston speed; in fact, for any given dimensions of cylinder the power developed is within limits roughly proportional to the piston speed. Taking a piston speed of 1,000ft. per minute and 5in. stroke, we require 1,200 revs. per minute = 20 revs. per second. Assuming a velocity of flight of about 80ft. per second the effective pitch of the screw requires to be 4ft., or approximately equal to half the diameter of the screw, instead of at least equal to the diameter, as in a good marine propeller.

It is, of course, not difficult to gear down from the engine to the propeller, in fact, this has been frequently done, but, since gearing involves a tax of approximately 5 per cent. of the horse-power, it is evidently better to drive direct and sacrifice something in the efficiency of the propeller, more especially as this course involves a far lower torque on the propeller shaft, and consequently a lower recoil torque on the framework of the machine.

(*To be continued.*)

* The average of a number of war-vessels, capable of about 18 to 20 knots speed, gave the figure 1·3 per cent. Two typical low-speed merchantmen (from particulars supplied by the builder) gave exactly 1 per cent.

Incorporated Municipal Electrical Association.—The 19th annual convention of this association will be held at Birmingham from June 15th to 20th, when the following papers will be read and discussed: "The Commercial Development of Electrical Supply in Towns of Moderate Size," by Mr. W. A. Vignoles; "The Design and Operation of Modern Boiler-house Plant," by Mr. S. E. Fedden; and "The Standardisation of Tariffs," by Mr. J. H. Bowden. The annual dinner will take place at the Grand Hotel, Birmingham, on Tuesday, June 16th, at 7 p.m.; and the annual general meeting at the Midland Institute, at 10 a.m. on Friday, June 19th.

INDUSTRIAL AND TRADE NOTES.

Contracts for New Battle-ships.—The Admiralty have placed the provisional contracts for two of the four battle-ships of the 1914-15 programme, the order for one going to the Fairfield Company, of Govan, and the order for the other to Palmers Company, of Jarrow.

New Seaplanes for the Admiralty.—The British Admiralty have ordered from Messrs. John Samuel White & Co., of Cowes, seven more seaplanes. They will be larger than the two machines this firm have recently built and delivered to the Calshot Naval Air Station, and will contain some new features, the result of experience gained in flying this type of machine. They will have 200 h.p. radial cylinder engines of French make, similar to the other White seaplanes.

Submarine Building on the Clyde.—Messrs. William Beardmore and Co., Dalmuir, are erecting a double shed for the construction of submarines. This shed will provide two parallel berths, on each of which a submarine can be built. By having the vessels built in these sheds the maximum of privacy will be obtained, while the submarines will be launched into the Clyde down the gradient which previously formed the slipway on which the Clyde Trust dredgers and barges were hauled up for repairs. The firm's fitting-out basin, which is near at hand, is large enough and deep enough for carrying out extensive experiments with new submarines.

Free Importation of Certain Machine Tools into Australia.—The Board of Trade have received, from H.M. Trade Commissioner in Australia, copy of Customs By-laws (Nos. 290-1) dated March 5th & 18th last, respectively, which provide for the free importation of the following machine tools, under Customs heading No. 166, into the Commonwealth of Australia, with effect from the under-mentioned dates: Machine tools and parts (but not the motive power, engine combination or power connections, if any, when not integral parts of the exempt machine): For metal working—bench filing machine, from December 14th, 1913; for hammers—electrical hand riveting machine, electrical hand chipping machine, February 16th, 1914.

Oil Fuel for the Navy.—A contract is, we learn, being arranged between His Majesty's Government and the Anglo-Persian Oil Company for a supply of a large quantity of fuel oil for delivery over a term of years. An agreement has been concluded whereby the Government is to subscribe for two millions ordinary shares and £200,000 debentures as soon as the necessary Parliamentary sanction has been obtained. This additional capital is required for considerable extensions of the company's existing pipe lines, refineries, tankers, &c., which will be necessary to enable the company to carry out this large contract. A meeting of the shareholders has been called for the 29th inst. for the purpose of authorising the increase of capital and for making certain alterations in the articles of association.

Royal Commission on Railways.—At a meeting of this Commission held in London, on the 22nd inst. Mr. H. F. West, for many years employed on the London and North-western Railway, advocated nationalisation of the whole railway system on the ground of the wastage and duplication which the present system involved. There were, he said, too many boards of directors, general managers, and higher officials. One result of nationalisation would be a saving of two-thirds of the present office staff. The capital of the companies could be exchanged for Consols, and the results arising from the displacement of the office staff could be mitigated by their absorption into other branches of the service. He believed that nationalisation would mean an increased revenue all round, even if the present charges were reduced. There would be no need to dispense with the present premises, but these could be made more economical use of. All short lines should be electrified.

The Co-partnership Association.—The annual meeting of this Association was held in London on the 21st inst., Mr. H. G. Chancellor, M.P., presiding. The object of the association, as set out in the 28th annual report, was to bring about an organisation of industry based on the principle of labour co-partnership, so that all who were engaged should share in the profits, capital control and responsibility. With that view it sought in the co-operative movement to aid by its propaganda and advice all forms of production based on those principles, and to induce employers and employed to adopt schemes of profit-sharing and investment tending in the same direction. The chairman, after tracing the existence of the idea 40 years back, said that it was laid down that labour had first claims upon industry, and should be paid a full and just wage—whether a trade union existed or not—while at the same time being careful that the interests of capital should be safeguarded, and that, after all wages were paid, capital should receive fair remuneration. The result was that many firms had agreed to the idea, and had gone so far as to allot the profits as

shares in the business, and many firms throughout the country were now alive to the fact that the principle was one to be followed. Several gentlemen gave addresses illustrating the manner in which they had co-operated with their workpeople, with mutually beneficial results.

Proposed Eight Hours Day in Shipyards.—The annual conference of the Federation of Engineering and Shipbuilding Trades was recently held at Nottingham, when the question of an eight hours day was discussed. The officials had been in negotiation with the engineering employers' federation for a long time, and a committee representing both the employers and the workmen had been appointed. This body had, however, only met once, when the whole question of a considerable reduction in the hours of employment was discussed. Anticipating a diminished output as the result of a reduction, the employers asked for certain guarantees, and the conference dealt with the question at considerable length. In the end they decided that it would be impossible to give any guarantees as to the maintenance of output, but arrived at the conclusion that with better timekeeping and a number of administrative economies no diminution of the output would be likely to follow the establishment of an eight hours day. For further consideration of the matter a meeting of the two subcommittees was arranged to be held in London, when it is hoped the differences between the employers and the men will be smoothed away, so as to bring a practical solution within view.

Queensland Mining Industry.—We have received an advance copy of the annual report of the Under-Secretary for Mines (Mr. A. R. Macdonald) on the Queensland mining industry, for the year 1913. This states that the value of last year's mineral output was £3,857,881, a decrease, when compared with that of the preceding year, of £317,474. The increase in the production of the industrial metals hardly fulfils the anticipations formed with regard to it, although disappointment in this respect may fairly be attributed to causes incidental to, rather than inherent in, the industry. Thus, fires and industrial disputes have interrupted the regularity of copper smelting at Cloncurry, and delay in the delivery of machinery, together with paucity of skilled labour, have postponed the promised increase from Mount Morgan. Tin, wolfram, and molybdenite have fairly maintained their positions, but it is in coal alone that any pronounced and satisfactory advance is apparent, the years's output of more than 1,000,000 tons being 100,000 in excess of that of the preceding year. The hope of any substantial increase during the current year has, to some extent, been dimmed by the recent closure of the works at Chillagoe, and the contemplated relaxation of activity at the Great Fitzroy mine.

The Manchester Steam Users' Association.—The annual report of this Association, presented at the annual meeting held on Tuesday last, states that at the close of 1913 the number of boilers under inspection, and the revenue for the year, constituted a record in the Association's history. As many as 9,942 "internal," "flue," and "entire" examinations of boilers were made, the highest number ever attained. No boiler under the Association's care burst during the year, and it is pleasing to record that at the end of 59 years no life has ever been lost from the explosion of any boiler which the Association has inspected and guaranteed as safe. In some of the boilers examined for enrolment, defects were met with which, if not detected, would probably have led to serious consequences, thus showing clearly the great importance of competent independent inspection. A summary of the failures of steam pipes on board steamers due to vibrations was laid before the Institute of Naval Architects by Mr. C. E. Stromeyer, chief engineer, and will be extended to steam pipes on land in the next published memorandum. A series of tests on a torsion fatigue testing machine has now been completed, and a new machine on which fatigue tests can be conducted, both as regards torsion, bending, and push and pull stresses, has been fitted up on the Association's premises, and will shortly be available for the carrying out of such tests.

Trade Circulars and Catalogues.—We have received from Messrs. Mather & Platt, Ltd., Manchester, a booklet describing and illustrating various types of filters manufactured by them for industrial purposes. A good deal of attention has of late years been paid to the subject of water purification, and where it is used in considerable quantities, as it is in many industries, the adoption of automatic and mechanical filtration often permits of very substantial economies being effected. In the construction of apparatus of this kind the firm have had a wide experience, and we commend the pamphlet to the attention of all who are in the market for plant of this kind.—Messrs. David Bridge & Co., Ltd., Castleton, near Manchester, send us a copy of a new illustrated catalogue they have just issued of Cummins' patent horizontal hydraulic baling press for pressing and baling cotton, jute, wool, or any other kind of fibrous material. The special points of the press are extreme rapidity, high density, end pressing, and horizontal action. The press is capable of handling bales weighing from 300lbs. up to 600lbs. or more if required. All parts of the press being above ground and on one level only, render examination and manipulation easy in comparison with other presses, which are often on two or three levels in pits and channels, that render them difficult of access and unhealthy to work. Another feature claimed for the press is that it is less than half the weight of most Indian presses and consequently effects a considerable saving in up-country freight from the port of arrival. Messrs. J. Kaye & Sons, Ltd., of Leeds, send us an illustrated catalogue of their oil cans, lamps, and lubricating specialities.

Trade of the United Kingdom. The trade of the United Kingdom with the Dominions and chief foreign countries is dealt with in White Papers recently published. Taking the last years for which figures are available—1913 for imports, and 1912 for exports—the figures for imperial trade are:—

	Imports.	Exports.
Canada	£30,488,000	£28,7[illegible],000
Australia	£38,065,000	£38,589,000
New Zealand	£20,338,000	£12,391,000
South Africa	£12,301,000	£22,040,000

The imports from South Africa are exclusive of diamonds, valued at £11,986,083. Our trade with the leading foreign countries was:—

	Imports.	Exports.
United States	£141,652,000	£56,862,000
Germany	£80,411,000	£41,429,000
France	£46,353,000	£41,936,000
Argentina	£42,485,000	£23,728,000
Russia	£40,271,000	£15,026,000

Altogether, our imports from these five countries, and Austria-Hungary, Italy, Spain, China and Japan, totalled £390,459,000. Our exports to these countries totalled £243,919,000 of which £150,955,000 was subject to duty.

Launch of a Large Geared Turbine Steamer.—There was launched from the yard of Scotts' Shipbuilding and Engineering Company, Greenock, on Saturday last, the twin-screw steamer "Transylvania," built to the order of the Cunard Steamship Company for their service between Fiume and New York, but which has since been transferred to the service of the Anchor line between Genoa and Naples and New York. The vessel will be propelled by twin screws driven by Parsons turbines transmitting their power through Parsons mechanical gearing. She will be the largest passenger steamer in existence propelled by geared turbines. Her dimensions are, length, 567ft.; breadth, 66ft. 6in.; and depth, 45ft. The machinery is the first installation of geared turbines to be fitted in a large trans-Atlantic vessel. The twin screws are driven by turbines of the Parsons type working through reduction gearing. The gear wheels are about 10ft. in diameter and 5ft. in breadth. They are each driven by two turbines working in series and running at about 1,500 revs. per minute. An astern turbine of the impulse-reaction type is incorporated with each low-pressure ahead turbine. The arrangements are such that either the high-pressure turbine or the low-pressure turbine can be used independently. Thus the derangement of one turbine will not prevent the vessel proceeding on twin screws. A very complete system of forced lubrication is installed for all turbine and gear wheel case bearings. The boiler installation consists of six large double-ended Scotch boilers, working under natural draught at a pressure of 210lbs. They are arranged in two groups of three each in separate boiler rooms.

The Welding and Cutting of Metals.—The annual business meeting of the Glasgow and West of Scotland Association of Foremen Engineers and Draughtsmen was recently held in Glasgow. The vice-president, Mr. George Watt, Dumbarton, was elected president for the session 1914-15, and Mr. John Mercer, Carron, vice-president. The treasurer, Mr. Robert Scott, and the secretary, Mr. William Davie, were re-elected. A paper on "Oxy-acetylene Plants and Their Application to the Welding and Cutting of Metals" was afterwards read by Mr. C. Linwood. The lecturer touched on the properties of oxygen and acetylene gases and the chemical changes which take place in the oxy-acetylene flame, with their effects on welds. Various types of acetylene generators were described, as well as the other items which constitute a plant. The difficulties experienced in welding the more common metals were gone into, along with the causes of these difficulties and the best methods to adopt to surmount them. A number of samples of oxy-acetylene cutting were shown, as well as samples of welding in steel, cast iron, copper, and aluminium. Several types of blow-pipes, cutters, regulators, and accessories were also shown. A discussion followed the reading of the paper.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1913.

Steam engines, pumps, cranes, and winches. Gibson. 5757.
Self-driving motors. Tellier. 10211.
Rotary pumps or motors. Tabard. 10485.
Thermostats and regulating valves. Arndt. 10555.
Heating installations. Castellazzi. 10590.
Nut locking devices. Jacobs. 10640.
Means for delivering fluids from pumps. Knowles & Goreham. 10651.
Governors for hydraulic motors. Pitman. 10716.
Clutches. Saunders & Smith. 10774.
Starting of internal combustion engines. W. & G. Du Cros, Ltd., and Turpin. 10798.
Drop stamps or hammers. Alldays & Onions Pneumatic Engineering Company, and Wilson. 10831.
Explosion turbines. Pichard & Pichard. 11107.
Valve mechanism for internal combustion engines. Lafon. 11112.
Belt fasteners. Terry. 11130.
Fly or driving wheels. Waller. 11273.
Welding of rail joints. Wattmann & Tudor Accumulator Company. 11847.
Steam generators. Pielock. 11944.
Hydraulic apparatus. Thatcher. 12081.
Means for coupling shafts. Lowden. 12330.
Marine engine governors. Ramsay & Jackson. 12355.
Furnace grates. Hill. 12451.
Cup ring packed pistons or plungers. Trist. 12454.
Rotary engines and compressors. Rollison. 13062.
Distillation of coal. Stephenson. 13104.
Change speed gearing for motor road vehicles. Birmingham Small Arms Company, and Nicholls. 13574.
Construction of gas washer or scrubber. Fiddes. 13813.
Elastic fluid turbines. Warwick Machinery Company (1908). 14395.
Stuffing box packing. Cook. 14517.
Oil furnaces for heating and melting metals. Allday. 14581.
Railway couplings. Masters. 14668 and 14669.
Method of and apparatus for measuring gas. Julius Pintsch Akt. Ges. 15094.
Winches and hoists. Masters, Masters, & Tittley, Son, and Brickley, Ltd. 15136.
High speed circular saws. Hendee. 15177.
Nut lock. Hitchcock. 15645.
Internal-combustion engines. Feyens. 15961.
Railway rail joints. Ravn. 16294.
Air extracting device for the oil supplied to the fuel pump of an internal combustion engine. Allgemeine Elektricitäts Ges. 16399.
Liquid fuel pumps for internal combustion engines. Esnault Pelterie. 17181.
Starting gear for internal combustion engines. Leitner. 17189.
Railway rail-joints. Deppisch. 17257.
Machines for casting metals. Mann. 17724.
Combustion chambers of oil engines. Gardner. 17855.
Friction clutches. Bridge, Bridge, & Bradshaw. 18147.
Self propelled vehicles. Bailey. 18829.
Feed water distributors for steam generators. Casmey & Kirkwood. 18972.
Rotary moulding and compression machines. Karbowsky. 19315.
Carburetters of internal combustion engines. Laubenburg. 19355.
Apparatus for starting internal-combustion engines. Rowe. 20166.
Lubricators. Atkinson & Taylor. 21317.
Turret lathes. Herbert & Vernon. 21638.
Machines for cutting mitre and bevel gear wheels. Buck. 22132.
Power transmission gear. Hounsfield. 23064.
Pistons and piston rings. Childs. 23136.
Toothed gearing. Graemiger. 23955.
Internal combustion engines. Triumph Cycle Company, and Baylis. 24292.
Pumping engines. Davey. 25064.
Welding of rails. T. H. Goldschmidt Akt. Ges. 25180.
Jig conveyers. Geb. Hinselmann. 25719.
Transmission gearing. Lord. 26022.
Riveting apparatus. Siemens & Halske Akt. Ges. 27049.
Machines for coating metal plates with tin, terne, and other metal. Taylor. 27467.
Rotary liquid meters. Hill. 29036.
Annealing vessels. Romer. 29394.

1914.

Suction dredgers. Lobnitz. 918.
Utilisation of the waste heat of combustion motors for heating purposes. Semmler. 1491.
Apparatus for utilising wave power. Melander. 1544.
Adjustable roller bearings. Stepan. 1661.
Motor road vehicles. Ludwig, Kathe, & Sohn (Firm of), and Küster. 2405.
Gas producers. Weil. 4452.
Ball bearings. Söderlund. 5043.
Anti friction bearings. Petit. 6073.

ELECTRICAL, 1913.

Sparking plugs. Longford, Longford, & Clark. 7365.
Dynamos. Allgemeine Elektricitäts Ges. 7784.
Electrical conductors and supporting means for same. British Insulated & Helsby Cables, Ltd., Mordey, Astley, and Saunderson. 7805.
Electric motor control apparatus. Railing & Garrard. 10416.
Windings of dynamos. Allgemeine Elektricitäts Ges. 10608.
Electric switch operating mechanism. Pace & Kellum. 10717.
Incandescent electric lamps. British Thomson Houston Company. 10918.
Windings for dynamos. British Thomson Houston Company, and Taylor. 10919.
Wireless telegraphy. Marconi's Wireless Telegraph Company, and Ryan. 11106.
High frequency dynamos. British Thomson Houston Company. 11240.
Electromagnetic friction couplings. Forster. 13308.
Wiring of electric lighting installations. Hodgson. 15643.
Contact devices for electrical testing purposes. Evershed and Vignoles, Ltd., Clark, and Senior. 15968.
Electric batteries and accumulators. Sablon. 16684.
Solution for use in lead-accumulator cells. Rabbidge. 19782.
Voltmeter. Stephenson. 21143.
Electrical regulating devices. Bloxam. 25046.
Insulated electric conductors. Western Electric Company. 26684.
Arrangements for starting and regulating direct current electric motors. Cumont. 27988.
Electrolytic furnaces for the production of light metals. Ellis. 29418.
Electrical relays. Kemp & Lauritzen. 29448.

1914.

Switches for electric hand lamps. Hitzelberger, and New British Ever ready Company. 970.
Wireless telegraphy. Leimbach. 5535.
Electric starting and ignition systems for internal combustion engines. Kettering & Chryst. 6074.

METAL QUOTATIONS.

TUESDAY, MAY 26TH.

Aluminium ingot	86/– per cwt.
,, wire, according to sizes, &c. ......from	107/4 ,,
,, sheets ,, ,, ... ,,	112/– ,,
Antimony	£27/–/– to £28/10/– per ton.
Brass, rolled	$7\frac{1}{8}$d. per lb.
,, tubes (brazed)	$9\frac{5}{8}$d. ,,
,, ,, (solid drawn)	$7\frac{7}{8}$d. ,,
,, ,, wire	$7\frac{1}{8}$d. ,,
Copper, Standard	£63/2/6 per ton.
Iron, Cleveland	$51/1\frac{1}{2}$,,
,, Scotch	$57/1\frac{1}{2}$,,
Lead, English	£19/5/– ,,
,, Foreign (soft)	£18/17/6 ,,
Mica (in original cases), small	6d. to 3/– per lb.
,, ,, ,, medium	3/6 to 6/– ,,
,, ,, ,, large	7/6 to 11/– ,,
Quicksilver	£7/–/– per bottle.
Silver	$26\frac{1}{16}$d. per oz.
Spelter	£21/7/6 per ton.
Tin, block	£149/15/– per ton.
Tin plates, I.C.	12/3 per box.
Zinc sheets (Silesian)	£24/10/– per ton.
,, (Stettin; Vieille Montagne)	£24/12/6 ,,

Iron and Steel Institute: Paris Meeting.—In accordance with the announcement at the May meeting, the autumn meeting of the Iron and Steel Institute will be held in Paris on Thursday, Friday, and Saturday, September 17th, 18th, and 19th. On the conclusion of the meeting in Paris a visit will be made to Nancy, and Monday and Tuesday will be devoted to visits to the principal iron mines and metallurgical works of French Lorraine.



Vol. 33, No. 854

Edited by
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Telegrams: "Scientific," Manchester.
Telephone No. 6055 City.

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The Use of Cast Iron in Superheaters.

A recent report of the Board of Trade on the failure of a cast-iron stop-valve chest used in connection with superheated steam shows that some steam users do not yet fully realise the risks entailed by the use of this material in fittings exposed to steam of high temperature. The report in question, No. 2,283, is a very elaborate and exhaustive one, and to it are appended some interesting remarks on the chemical and micrographical structure of the material, and illustrating the deterioration this material undergoes through prolonged exposure to superheated steam. It scarcely needed this detailed scientific demonstration, however, for the majority of practical engineers who have had to deal with superheating apparatus arrived at this conclusion long ago. It is satisfactory, however, to know that it is now endorsed by the Board of Trade, though we could have wished the condemnation of cast iron had been more pronounced. It may be, as the Engineer Surveyor in Chief, in his remarks on the report, states, that "selected cast iron, carefully remelted under conditions favourable for keeping the content of phosphorus, sulphur, and other impurities, is successfully adopted for many vessels subjected to high and varying temperatures and pressures," and that "cast steel is undoubtedly preferable where ductility is of importance." But to our mind, there can be no question of the absolute unsuitability of cast iron for superheater, apparatus, or fittings, and for this reason its use should be rigorously excluded. Its virtues when manufactured under selected and favourable conditions may be all that is claimed for it, but unfortunately structures made of cast iron do not afford satisfactory methods of testing them, and without such tests too much is left to chance when safety of life and property is concerned. Cast steel or wrought steel should be the

only materials employed. It may be as well to remark here that copper is equally as objectionable as cast iron for superheater work, notwithstanding its ductility under normal conditions, for its tenacity rapidly diminishes with increase of temperature, beyond the ordinary range of saturated steam, and this fact, though well established, does not appear to be so generally known, judging from the failures that have been recorded through this injudicious use of copper.

Some Unsuspected Gas Engine Dangers.

THE June issue of "Vulcan" calls attention to one or two dangers in connection with gas engines which we do not think those who use this type of motor are generally aware of, but which it is desirable to bear in mind. One of the risks to which attention is drawn pertains to those engines fitted with magneto-ignition apparatus. It is, of course, no uncommon thing for gas to leak into the cylinder and form an explosive mixture therein, and it is very easy to forget, when barring an engine round for purpose of examining the crank shaft and crank pin journals, that if the magneto apparatus is not disconnected the explosive mixture may be ignited and thus cause a sudden and unexpected revolution of the engine. If anyone happens at the moment to be examining a working part he obviously runs risks of serious and even fatal injuries. That such risk is not hypothetical is manifest from the fact that sudden and unexpected movements of engines of this kind have come under the immediate notice of our contemporary. Another danger to which it calls attention, and where it might not be suspected, is in the vaporisers of suction-gas plants. These, of course, are not subject to any internal pressure, but for all that if they are fed with dirty water incrustation is liable to form and lead to overheating, and even fracture, as is illustrated by an actual example. Such a failure, it is pointed out, not only involves trouble and expense, but by permitting of the ingress of air may lead to a serious gas explosion. The moral of the incident is that vaporisers in suction-gas plants should be supplied with water which will not cause a deposit, and in any case be periodically overhauled.

The Danger of Stop Taps and Importance of Safety Valves in Circulating Hot-water Boilers.

A BOARD of Trade report just issued on the failure of a circulating hot-water boiler at Portrush on January 15th last once more draws attention to the importance of all boilers of this type being fitted with a safety valve or some similar means of affording relief in the event of excessive pressure. Usually this is brought about by accumulation of ice in the pipes during frost, but in the case under notice the explosion, although it occurred in the winter-time, was not due to the weather, but simply to an accumulation of deposit and incrustation finding its way into the boiler inlet pipe and partially blocking one of the stop taps fixed therein, with the result that the circulation was impeded and the supply of water to the boiler partially or wholly cut off. Steam was then generated in the boiler more rapidly than it could escape through the orifice of a tap in the outlet pipe, and eventually the pressure reached a point which the boiler could not resist, and it burst violently, killing the stoker in the hotel—who was in the act of drawing the fire at the time—and severely injuring the manager and another hotel servant. It appears that trouble had been experienced with the working of the boiler on several occasions, and a few days before the explosion a plumber who was sent for on account of unusual cracking noises in the pipes found the outlet pipe partially choked with scale. This he remedied by fixing a new pipe, but as the supply of water was not satisfactory—an evident proof that the circulation was defective—he had to make several further visits, the last being on the day of the explosion, when, in his opinion, he left the boiler in order; but as the noises in the pipes recommenced the kitchen-maid sent for a mechanic engaged on the premises, who at once proceeded to draw out the fire, with the results stated. When the Board of Trade surveyor examined the apparatus he found that the hot water supply tank contained a quantity of deposit, which was easily stirred up and swept forwards into the supply pipe of the boiler when any water was drawn from the system. Further, that a stop tap placed in this supply pipe could be very easily choked, and there can be little doubt the explosion arose in the manner suggested. There was an "escape pipe" open to the atmosphere fixed to the supply tank to relieve any excessive pressure therein, but this, under the circumstances, could afford no relief to the boiler in the event of the two circulating pipes between the supply tank and the boiler getting blocked by incrustation or the closing of taps, and in any case we agree with the report that where relief pipes are fixed they should be attached direct to the boiler and not to the supply tank, or the "copper cylinder," as it is usually termed. Objection to such escape pipes as a means of relief is that in frosty weather the upper end, which generally terminates near the roof, is liable to become choked with a plug of ice by the condensation and freezing of the slight vapour escaping from it. For this reason the "escape pipes" cannot be regarded as an absolute safeguard against excessive pressure. To secure this nothing is simpler or more reliable than a small dead-weight safety valve attached directly to the boiler itself, and in the absence of such a safeguard the presence of stop taps in the course of the circulating pipes is always attended with a certain amount of risk.

Sir Joseph Wilson Swan.—We regret to announce the death, at his residence, at Warlingham, Surrey, on the 27th ult., of Sir Joseph Wilson Swan, the inventor of the incandescent electric lamp. He was born on October 31st, 1828, at Sunderland, and after being educated at a private school was apprenticed to a firm of druggists, and eventually entered into partnership with John Mawson, a chemist of Newcastle. He worked out what is now known as the "carbon process," and greatly improved the methods of photo-mechanical printing. It is due to this invention, patented in 1864, and best known as "Autotype," that we owe the finest reproductions of famous pictures. Another of his inventions was the "bromide printing paper," now universally used as a means of exceedingly rapid photographic printing by artificial light. This invention was first made and patented by Mr. Swan in 1879. He began to experiment in electricity, and to construct electrical apparatus when but 20 years old. He first got on the track of his great discoveries with regard to the incandescent lamp in the year 1845, when he saw a platino-iridium wire made incandescent by the chemist Staite. From this time he always kept before him the idea of making this incandescent wire useful for lighting purposes in every day life, and by 1860 he had managed to find the means of producing slender filaments of carbon strong and elastic enough to serve his purpose, but it was not until 1879 that a practical lamp was evolved. Mr. Swan not only received honorary degrees from various universities, and a knighthood in 1904, but he was decorated in Paris, 1881, as a Chevalier of the Legion of Honour. He had been president of the Institution of Electrical Engineers, of the Society of Chemical Industry, and of the Faraday Society. He was the recipient of the Hughes Medal for scientific discoveries in 1904, and of the medal of the Society of Chemical Industry in 1903.

DESIGN OF SURFACE-CONDENSING PLANT.*

BY W. VINCENT TREEBY.

BEFORE determining the size of machines to recommend for any particular enquiry it is, of course, absolutely necessary to obtain full particulars of the existing conditions and requirements. These should comprise the following:

(1) Usual barometric conditions, which will depend upon the elevation or altitude of the country in which the plant is to be installed. It is usually necessary to have this information as the vacuum specified is generally given as a percentage of the prevailing barometer.

(2) Quantity of exhaust steam to be condensed. This is usually stated in pounds per hour. If any superheat is likely to be present in the exhaust steam this should be noted.

(3) Source of exhaust steam, high, mixed, or low-pressure turbines, reciprocating engines, distillating apparatus, vacuum pans, &c. If the steam is received from a reciprocating steam

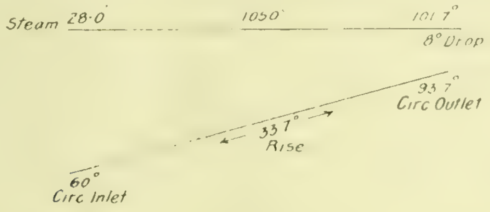


FIG. 1.

engine an efficient oil separator should be provided between the engine and the condenser.

(4) Vacuum required, which is generally, in English-speaking countries, stated in inches of mercury, referred to a 30in. barometer. It is frequently, however, stated as a percentage of the barometer. This latter method is to be avoided, as with a given percentage the absolute pressure in the condenser, which is the point we are really seeking, may be greatly different. For example, suppose a vacuum = 90 per cent. of the barometer is specified. This with a 30in. barometer will give an absolute pressure in the condenser of 3in. Hg. or 27in. vacuum, whilst with a 24in. barometer the absolute pressure will be 8·4in. Hg. or 21·6in. vacuum. Putting it another way, suppose it is required to maintain an absolute pressure of 3in. Hg. in the condenser. This on a 30in. barometer = 27in. vacuum, or 90 per cent., whilst on a 24in. barometer we have 21in. vacuum, or 87·5 per cent. of barometer reading. It would be more satisfactory to always state the vacuum in absolute inches of mercury or pounds per square inch. When dealing with the question of vacuum it is important to note that whatever vacuum is defined, from a condenser manufacturer's standpoint, it is measured at the condenser exhaust branch unless specially stated to the contrary.

(5) *Circulating Water.*—The temperature is usually given in English-speaking countries in Fahrenheit degrees. The source, whether sea, river, brook, or cooling towers. The quality, whether acidulated, muddy, chalky, greasy, &c. If possible a sample should be obtained for analysis. It will be obvious that if acid or salt water be used the parts of the condenser and circulating pumps must be suitably designed to handle same in order to maintain the continuous efficiency of the plant. The size of the condenser tubes will depend to some extent on the cleanliness of the circulating water and the possibility of suitably screening same. The quantity: If there is any limit to the quantity of water available same should be ascertained, and to what extent, as the degree of vacuum possible of attainment depends on this figure. If the circulating water has to be purchased it may be more economical to install a cooling tower either of the natural or forced-draught type, depending on the space provided.

(6) Energy available for driving the auxiliaries, whether steam or electrical.

(7) Having obtained the particulars called for in the foregoing, make a point of collecting any further information special to the job in hand that may be of service in suitably proportioning the plant offered, such as location, space available, run of existing pipes (if any), whether pumps are to be steam or electrically driven, steam pressure available, volts, amperes, and, if alternating current, frequency, and number of phases of electric supply, prevailing wet bulb and air temperature conditions, &c.

We will now assume that the necessary particulars have been taken as follows, and proceed with the proportioning of the various apparatus.

Steam.—25,000lbs. of steam per hour from a high pressure steam turbine. Dryness factor 85 per cent. at turbine exhaust.

Vacuum.—2in. Hg absolute = 28in. vacuum with a 30in. barometer = 0·98lb. per square inch.

Circulating Water.—Temperature 60 Fah.; quality, clean river; quantity, relatively unlimited.

System.—Entirely new condenser may be arranged directly under turbine exhaust, with air and circulating pumps alongside the turbine foundations. Pumps to be electrically driven by direct-current motors.

Condenser.—We will assume this to be of the counter-current type of cylindrical form, with ratio of length of shell to diameter of 2 to 1. Solid-drawn brass tubes of [illegible] in. external diameter and 18 S.W.G. thickness. Exhaust and air pump suction branches arranged on longitudinal centre line of shell, and preferably at mid-length of shell.

Air Pumps.—Vertical, single-acting, suction, valveless, three-throw pattern, with single reduction gearing. These pumps may be driven direct with some slight advantage as regards quietness and mechanical efficiency, but the usually abnormal proportions of the motor designed to run at the slow speed necessary, with its attendant high costs, make this method of drive extremely rare.

Circulating Pump.—Centrifugal type.

Having settled the type and design of apparatus we now have to determine the requisite capacities.

Circulating Water.—The first thing to settle is the quantity of circulating water required. This we obtain as follows: The latent heat in the steam is assumed to be = 1,050°. This figure is, of course, not strictly true, as the heat content will vary with the absolute pressure and also with the degree of saturation at entry to condenser. The figure taken, however, is generally on the large side, and in the end does not materially affect the results. Lay out the diagram shown in Fig. 1, the top line representing the steam conditions, *i.e.*, pressure, heat, and temperature values. The bottom line represents the circulating water conditions, *i.e.*, inlet temperature on the left and outlet temperature on the right.

Before we can settle on the outlet temperature of the circulating water we must determine the value of the expres-

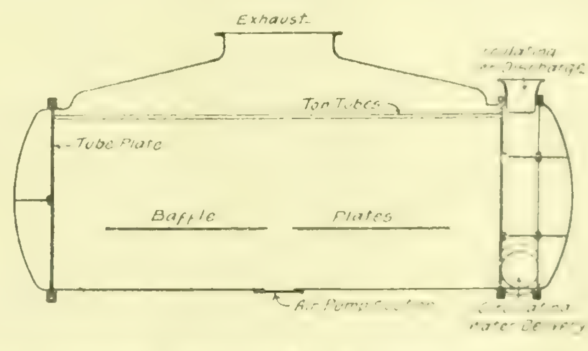


FIG. 2. DIAGRAMMATIC ARRANGEMENT OF CYLINDRICAL SURFACE CONDENSER.

sion indicated as "drop." Briefly, "drop" represents the temperature difference between the saturated steam at the given vacuum and the circulating water at the condenser discharge. The value of "drop" depends upon several variables, both individually and collectively. Many experiments have been carried out with a view to constructing a formula to give the value of "drop" under certain conditions, and several formulæ have been constructed and found to be approximately correct when applied to existing conditions. Those, however, that the author has met with have been awkward to use and have consequently been put aside.

Some of the variables affecting the "drop" are as follows: (1) Condensation rate = pounds of steam condensed

* Paper read before the Junior Institution of Engineers, May 15th, 1914.

per square foot of tube surface; (2) degree of vacuum to be maintained; (3) temperature of circulating water at inlet; (4) velocity of circulating water through the condenser tubes; (5) ratio of tube area (internal) to surface of tube element.

Ordinary rectangular or cylindrical surface condenser dealing with steam up to 20,000lbs. per hour, 15° to 10° Fah.; above 20,000lbs. per hour, 12° to 8° Fah.

To proceed with our design calculations, a value of 8° Fah. is applicable to our conditions, and we therefore insert this figure in the diagram, Fig. 1. Now, deducting the drop of 8° Fah. from the steam temperature of 101·7° Fah., we obtain the circulating water outlet of 93·7° Fah. Deducting the value of the inlet water temperature, 60°, from this outlet temperature gives a rise in temperature of circulating water during its passage through the condenser of 33·7° Fah.

Now if we divide the latent heat value of 1lb. of saturated exhaust steam = 1,050° Fah. by the temperature rise of the

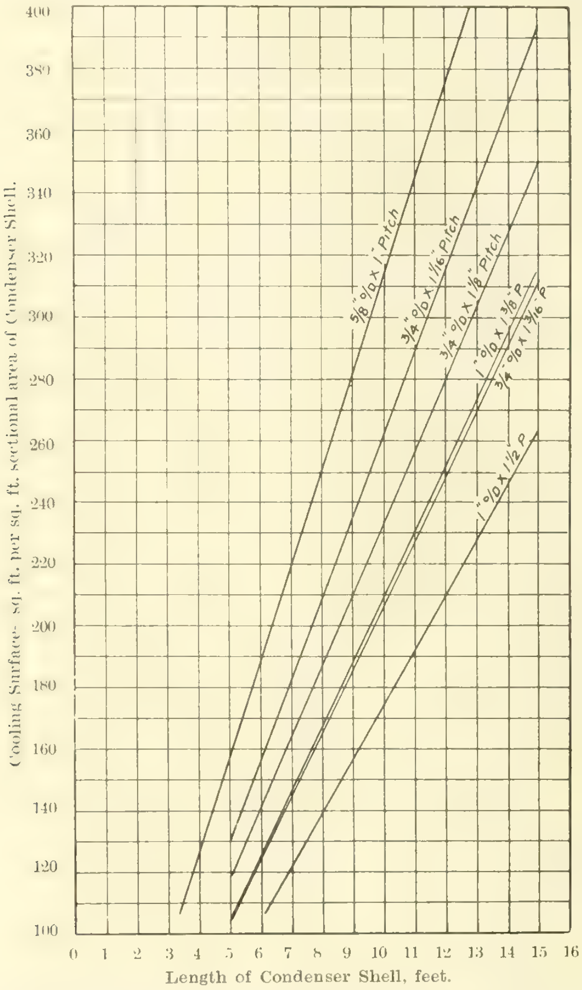


FIG. 3.—Tubes ⅝in., ¾in., and 1in. external diameter, 18 S.W.G. thickness. 60° pitch. Arranged for two passes of circulating water. For four pass condenser deduct approx. 30 per cent. surface shewn. If steam dome is dispensed with, necessitating provision of steam paths between tubes, suitable correction should be made.

circulating water = 33·7°, we will obtain the quantity in pounds of circulating water necessary to condense 1lb. of steam at the degree of vacuum specified. This $\frac{1,050}{33 \cdot 7} = 31 \cdot 7$lbs. of circulating water per pound of steam, and the total quantity of circulating water we shall require will be =

$$\frac{25000 \times 31 \cdot 7}{60 \times 10} = 1,330 \text{ imperial gallons per minute.}$$

It may be questioned as to why the constant 1,050 is taken as representing the latent heat of the steam. This value is, of course, correct for dry saturated steam at a vacuum of 29·6in. Hg., but when dealing with condensing apparatus dry saturated steam is practically never met with. With steam turbines the dryness factor of the exhaust steam usually ranges between 83 per cent. to 87 per cent., so that if we accept the value of 1,050° it will be seen that we are well on the safe side for all vacua generally considered. Some authorities work on a latent heat value of 1,000°, and the author believes that one firm uses a figure as low as 900. It is as well, however, not to cut things too fine, so that the value of 1,050 is recommended.

Condenser.—Having obtained the quantity of circulating water required, we next proceed to determine the amount of condensing surface required. The amount of condensing surface depends upon the weight of steam that can be condensed per square foot of surface, that is, the condensation rate. This is based upon the mean temperature difference of the steam and circulating water.

When dealing with perfect gases the mean temperature difference follows the hyperbolic law, but in a steam condenser we have to deal with not only steam but non-condensable air as well. This air upsets the above-mentioned law, and the arithmetic mean gives us a more correct value and in addition is much more simple to calculate. The author is fully aware that some authorities still base the mean temperature difference on the hyperbolic law, but he cannot find any justification for so doing.

Referring back to the diagram, Fig. 1, we see that the temperature difference at the beginning is 41·7° Fah. and at the end 8° Fah. The mean temperature difference will then be $\frac{41 \cdot 7 + 8}{2} = 24 \cdot 85°$ Fah. Various values have been stated by different authorities for the mean heat transmission rate per degree mean temperature difference per hour, but the author considers the following table gives a fair representation of what may be expected in practice under normal conditions:

Heat Transmission Rate.

1. Ordinary rectangular and cylindrical counter-current surface condensers for reciprocating engines, up to 20,000lbs. per hour	325 B.T.U
2. Ordinary rectangular and cylindrical counter-current surface condensers for reciprocating engines, above 20,000lbs. per hour -	350 ,,
3. Ordinary rectangular and cylindrical counter-current surface condensers for turbines, up to 20,000lbs. per hour - - -	375 ,,
4. Ordinary rectangular and cylindrical counter-current surface condensers for turbines, above 20,000lbs. per hour - - -	390 ,,

From the foregoing table we find the value 390 B.T.U. meets our case, and we then proceed to calculate the condensing surface required as follows:—

$$\frac{\text{Lbs. of steam per hour} \times 1050}{\text{Mean temperature difference} \times \text{heat transmission rate}}$$

$$\frac{25000 \times 1050}{24 \cdot 85 \times 390} = 2710 \text{ sq. ft.}$$

This value gives us a condensing rate of $\frac{25000}{2710} =$ 9·25lbs. per square foot.

Condenser Tubes. — Having determined the condensing surface we may proceed to the number and length of tubes to give this surface. The external surface area of a ¾in. diam. tube = 0·1963 sq. ft. per lineal foot. Maintaining the ratio of shell length to diameter of 2 to 1 as previously recommended, we find that with a tube pitch of 1⅛in. in the top half, allowing ample entrance area between the tubes for the steam and $1\frac{1}{16}$in. pitch for the bottom half, we shall require an internal diameter of shell of 4ft., with a length between tube plates of 10ft.

The number of tubes per square foot tube plate area, equally pitched at an angle of 60°, may be obtained from the following formula:—

$$N = \frac{A}{0 \cdot 866 P^2}$$

where N = number of tubes.

A = area of tube plate in square inches.

P = pitch of tubes in inches.

When using this formula for determining shell diameters allowance must be made for necessary stays and diaphragms in circulating water heads.

To proceed with our calculations, the number of tubes required will be equal to $\frac{2710}{10 \times 0{\cdot}1963}$ = 1,380 – $\frac{3}{4}$in. external diameter × 18 S.W.G.

The internal sectional area of these tubes will be equal to

$$1{,}380 \times 0{\cdot}00233 = 3{\cdot}22 \text{ sq. ft.}$$

The volume of circulating water $\frac{1330 \times 0{\cdot}1605}{60}$ = 3·56 cub. ft./second. If we make the circulating water flow through the condenser four times the area of flow will equal $\frac{3{\cdot}22}{4}$ = 0·805 sq. ft., and the mean velocity of flow will equal $\frac{3{\cdot}56}{0{\cdot}805}$ = 4·42ft. per second. This velocity is very reasonable, but might with advantage be increased if it did not tend to increase the ratio of shell length to diameter. Another objection to increased tube velocity is the rapid building up of the frictional head and consequent increased power required to operate the circulating pump.

Having determined the main dimensions of condenser surface of shell we may now fix up the sizes of exhaust and circulating water branches. It is customary to proportion the exhaust connections upon certain steam velocities dependent upon the degree of vacuum required and an assumed steam dryness factor, which have proved satisfactory under normal conditions in practice. The following table will serve as a guide:—

Vacuum—inches Hg. ...	27·0	27·5	28·0	28·5	29·0
Dryness fraction	0·87	0·86	0·85	0·84	0·83
Steam velocity ft./sec. .	230	260	300	350	460

On reference to a steam table it will be found that saturated steam at an absolute pressure of 2in. Hg. will have a volume of 338 cub. ft. to the pound. The required exhaust inlet area will then be equal to—

$$\frac{25000 \times 0{\cdot}85 \times 338 \times 144}{3600 \times 300} = 655 \text{ sq. ins.}$$

giving a diameter of 29in.

In order to permit of turbine working whilst the condenser and pumps are being overhauled it is necessary to provide an atmospheric exhaust connection. This valve is invariably of the automatic type, so as to come into operation when the pressure in the condenser rises to one or two pounds above atmosphere, due to sudden shutting down of the air or circulating pumps, and so prevents damage occurring due to excessive pressure. The size of this valve may be satisfactorily based on a steam velocity of about 150ft. per second. When figuring on this velocity the steam volume is based on dry saturated steam at atmospheric pressure = 26·4 cub. ft. per pound. For the plant under discussion the area of atmospheric value would be equal to—

$$\frac{25000 \times 26{\cdot}4 \times 144}{3600 \times 150} = 176 \text{ sq. in.} = 15\text{in. diam.}$$

Circulating water branches are usually based on a mean water velocity of approximately 8ft. per second. If the circulating water pipes are long or tortuous it is advisable to cut this velocity down to 6ft. per second, or even less, or otherwise considerable power will be wasted in overcoming friction. Based on the foregoing the required area of circulating water branches will be equal to—

$$\frac{1330 \times 0{\cdot}1605 \times 144}{60 \times 8} = 64{\cdot}3 \text{ sq. in.} = 9\text{in. diam.}$$

The figures 0·1605 used in above calculations is a factor for converting gallons into cubic feet.

Summarising we now have a cylindrical surface condenser of 2,710 sq. ft. tube surface, 4 pass, 4ft. internal diameter × 10ft. between tube plates containing 1,380 – $\frac{3}{4}$in. O/S diameter × 18 S.W.G. untinned brass tubes, 29in. exhaust branch, and 9in. circulating water branches, the whole appearing somewhat as design shown diagrammatically in Fig. 2.

Air Pump. — Now we have to determine the size and capacity of air pump. It must be understood that the following procedure applies only to reciprocating air pumps, the method adopted for fixing up rotary air pumps being somewhat different. The quantity of air to be removed from the condenser by the air pump cannot be measured, so a capacity coefficient must be used based on experiment and experience. The capacities stated in the following table are ample for ordinary conditions, and may be used with confidence. It is arranged for working with the temperature of the circulating water entering the condenser.

Vacuum. Ins. Hg.	Circulating Water.	Inlet Temperature Deg. Fah.			
	60 Deg.	70 Deg.	80 Deg.	85 Deg.	90 Deg.
26in.	0.51	0.51	0.6	0.65	0.7 cub. ft. per minute
27in.	0.64	0.70	0.75	0.8	0.85 per lb. of steam per minute
28in.	0.725	0.79	0.85	—	
28·5in.	0.85	0.90	—	—	

We are handling steam to the quantity of 25,000lbs. per hour. Then our air pump will require a displacement of

$$\frac{25000 \times 0{\cdot}725}{60} = 315 \text{ cub. ft. per minute.}$$

As we are recommending a three-throw air pump, each section will have to deal with 105 cub. ft. per minute. For these conditions a three-throw air pump having cylinder

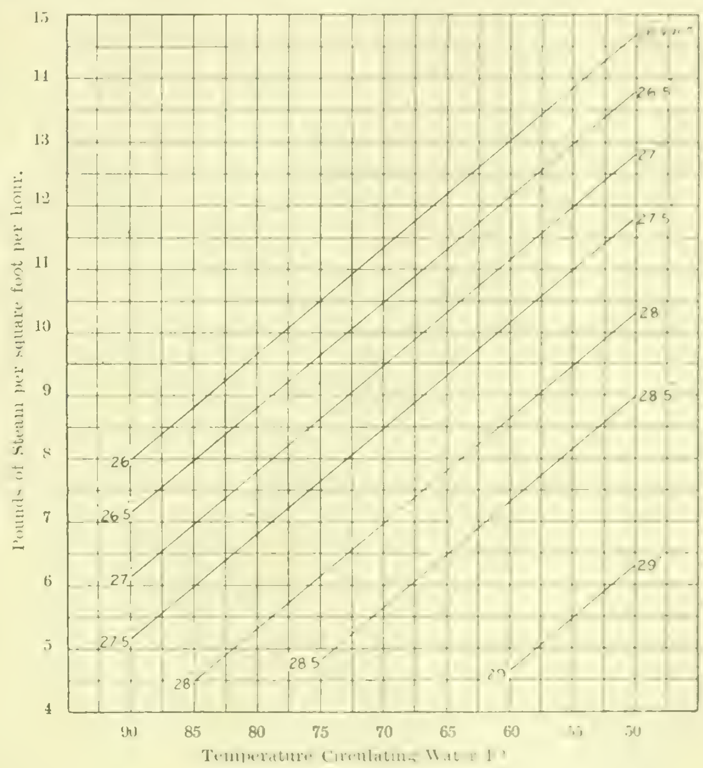


FIG. 1.

Drop 12°. Steam condensed per sq. ft. condenser surface [illegible] per hour. Basis 350 B.Th.U.'s per degree mean temperature difference per sq. ft. per hour.

$13\frac{1}{2}$in. diam. × 12in. stroke, and running at 110 revs. per minute, will be suitable. The ratio of driving gear with machine-cut gears should not exceed approximately 6:1, so that the speed of motor would be about 660 revs. per minute. For quietness in running the motor should be provided with a "fabroil" or "raw hide" pinion, these pinions being capable of running continuously without noise and have usually a very long life. It is advisable to proportion the motor, if anything, on the large size, as with careless operation it is possible to put on excessive overload on the machine when starting up. For the pump now proposed the motor should be capable of developing continuously about 12 b.h.p. at 660 revs. per minute.

Circulating Pump.—This pump would have to deal with the water as previously calculated, *i.e.*, 1,330 galls. per minute, and deliver same against a pressure or head consisting of suction lift, condenser friction, static head, and pipe friction.

Friction in piping may be calculated by Box formula.

$$H = G^2 \times L / (3d)^5$$

Where

H = friction in feet.

L = total length of piping, in yards.

d = internal diameter of pipe, in inches.

G = gallons per minute.

Friction bends may be estimated as follows: –

$$H = \frac{cV^2}{2g}$$

Where

H = friction in feet.

V = velocity, feet per second.

g = gravity = 32·2.

c = constant = 0·98 for bend with radius = 1 × bore of pipe.

= constant = 0·6 for bend with radius = 3 × bore of pipe.

= constant = 0·2 for bend with radius = 6 × bore of pipe.

$$V = \frac{G}{2{\cdot}04d^2}$$

Where G = gallons per minute.

d = diameter of pipe, in inches.

Friction in condenser may be estimated as follows:

$$H = \frac{V^2T\ (L + 7{\cdot}5)}{C}$$

Where

H = friction in feet.

V = velocity of water through tubes (feet per second).

T = number of passes (times water passes through tube).

L = length between tube plates.

C = constant = 100 for ⅝in. o/s diam. tubes.

= 140 ,, ¾in. ,, ,, ,,

= 160 ,, 1 in. ,, ,, ,,

For the condenser we have just fixed up the friction would be equal to—

$$\frac{V^2T\ (L + 7{\cdot}5)}{140}$$

$$= \frac{4{\cdot}42^2 \times 4\ (10 + 7{\cdot}5)}{140} = 9{\cdot}75 \text{ feet.}$$

We will suppose that the total head on the circulating pump will not exceed 25ft., which is a very usual figure for a compact plant; then our pump has to deliver 1,330 galls. per minute, against a total head of 25 feet. For these conditions we would require an 8in. centrifugal pump running at about 1,500 revs. per minute, with an efficiency of 60 per cent. The motor for driving this pump should be capable of developing continuously 17 b.h.p.

This completes the main apparatus of the condensing plant. The author would have preferred to treat the various sections more fully, but the time available for delivery would not allow of this. Many other points require attention, such as switchgear, gauges, thermometers, condenser and pump fittings, spare parts, &c., but the author must leave these for the present.

Design of Aeroplanes.—A report has recently been issued by the War Office Advisory Committee for Aeronautics as to the strength of construction desirable in aeroplanes in view of the increasing severity of conditions under which flights are undertaken. The Committee is of opinion that an attempt should be made immediately to produce machines having an increased margin of strength, and suggests that for the future no machine should be accepted for service unless the strength of the wing structure is such that the ratio of the breaking stress of any part to the stress produced in that part by a load equal to three times the weight of the machine is at least two.

FLEXIBLE CROWN STAY AND FLUE EXPANDER FOR LOCOMOTIVE BOILERS.

Two devices for use in connection with locomotive boilers have been devised by Mr. Wm. Kerr, of the Chicago and North-western Railway, and are shown in the accompanying cuts, for which, along with the following particulars, we are indebted to our American contemporary the "Railway Review." The flexible crown stay for radial-stayed boilers shown in Fig. 1 is made in the form indicated with the view to securing flexibility, and to avoid the necessity of making enlarged holes in the wrapper sheet in order to apply the bolts. By using jigs for getting the proper angles of the stays, the holes can be drilled and tapped before the firebox and the wrapper sheets are assembled. The short ball ends

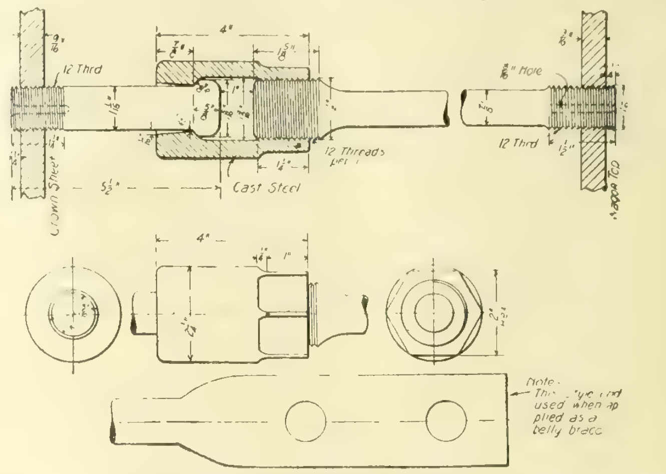


FIG. 1.—KERR FLEXIBLE CROWN STAY.

of the bolts, with the coupling nuts, can be inserted in the crown sheet prior to assembling, and after the firebox is in place the top ends of the bolts can be inserted in successive rows from the inside and uniform tension on all bolts can be secured in the tightening process by means of a wrench. The shape of the bolt permits of its being readily forged on a bolt machine. For the coupling nuts it is proposed that cast steel be used. The application of this idea in the construction of longitudinal braces is also illustrated.

The flue expander shown in Fig. 2, also devised by Mr. Kerr, is in use on the Chicago and North-western system. Its construction is such that the ends of the flues, which are allowed to protrude through the sheets for the purpose of

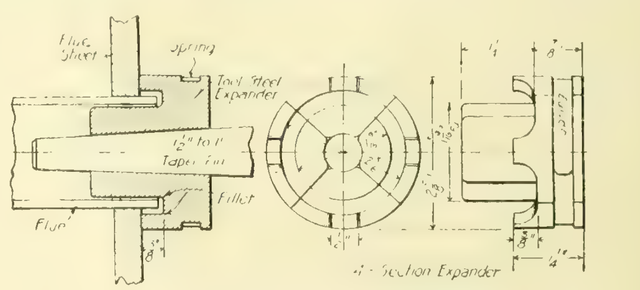


FIG. 2.—KERR SECTIONAL FLUE EXPANDER.

furnishing material from which to form the beads, are not injured in the expanding process. This is accomplished by providing each of the four segments of the expander with a ⅜in. projection which serves to keep the body of the expander that distance from the flue sheet. This expander is likewise useful for round-house work, as when flues are tightened by means of this device, the beads are not flattened or cracked as is likely to happen with those forms of expanders that allow the force of the blow from the air hammer to be taken on the end of the flue.

Depreciation of Railway Rolling Stock.—According to estimates made by the Pennsylvania Company, the locomotives and passenger coaches on that road will last 20 years. At the end of that period their scrap value will be 20 per cent. of the original cost. An allowance of 4 per cent. for depreciation and renewal is therefore made for locomotives and passenger stock; on freight cars it is 3 per cent. In the case of steel cars 4 per cent. is allowed.

INTERNAL STRAINS IN COLD-WROUGHT METALS, AND SOME TROUBLES CAUSED THEREBY.*

BY PROF. E. HEYN.†

(*Continued from page 503.*)

In certain cold-drawn alloys of copper, most markedly in those of copper and zinc, liability to cracking may often be revealed by dipping the piece to be examined in mercury or in solutions of mercury. In order to illustrate this, a round bar of an alloy containing 57·8 per cent. of copper, 40·8 per cent. of zinc, 0 per cent. of tin, 1·35 per cent. of lead, and only traces of iron and aluminium, had been cold-drawn from 28 mm. diam. to 25 mm. (reduction in sectional area equal to 26 per cent.). A portion of this bar, about 180 mm. in length, which was free from any superficial cracks, was dipped in a solution of nitrate of mercury. At the end of ten minutes the bar cracked with a sharp report, showing the cracks illustrated in Fig. 9. The fact that only longitudinal

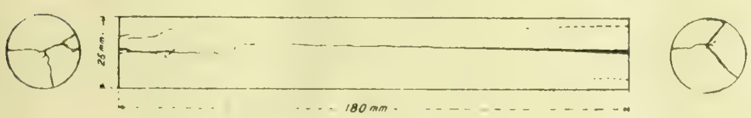


FIG. 9.

cracks were formed shows that the transverse internal strains in the bar prevailed over those in an axial direction. The further fact that the cracks start from the surface and gape shows that the internal transverse strains must be extension at the surface and compression in the core. The outer layer I of the section of the bar must press on the core like a ring shrunk on (Fig. 10). If by boring portions of the core are removed, the outer ring I can yield to its tendency to assume a smaller diameter, thus involving a decrease of the outer diameter d_a. The results of the measurements are tabulated below:—

	Inner Diameter d_i (millimetre) after		
	1. Boring. 4.	2. Boring. 10.	3. Boring. 16.
	Millimetre.	Millimetre.	Millimetre.
Decrease of outer diameter d_a ...	0·000	0·010	0·025

Since after boring out up to 16 mm. of inner diameter the greater part of the internal strains must have been relieved, it may be concluded that the remaining hollow cylinder would no longer develop cracks when dipped in a mercury solution. The experiment proved this to be the case. For similar reasons a portion of the cold-drawn bar no longer split up in the solution after the removal of a surface layer by turning down to an outside diameter of 15 mm. It was also of interest to determine the longitudinal internal strains in the cold-drawn bar mentioned above. The result is plotted in the diagram, Fig. 11. As was to be expected, the outer layers proved to be subjected to tension, the central core to compression. It must be noted here that the maximum tension is not immediately at the surface, but at some distance from it, and amounts to about 1,575 kgs. per square centimetre (22,400lbs. per square inch). The measurements began five days after the bar had left the drawing-die.

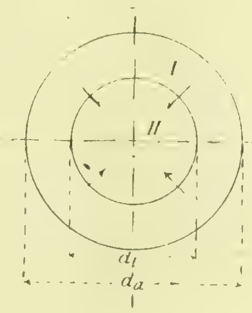


FIG. 10.

In order to see whether any change in the distribution of internal stresses would be brought about *in course of time*, another portion of the same cold-drawn bar was re-tested after having been left at rest for two years. The result of the measurement is shown in the diagram, Fig. 12, which would seem to indicate that some change in the distribution has been brought about, the maximum of tension having assumed a somewhat higher amount, viz., 1,870 kgs. per square centimetre (26,600lbs. per square inch), and the location of this maximum having shifted to the surface layer. The forces in equilibrium, amounting in the case of Fig. 11 to 2,520 kgs. (shaded area on one side of the horizontal zero line), have decreased to 2,290 kgs. at the end of two years (Fig. 12). This would seem to show that the potential energy did not change materially in course of time. I wish to postpone definite conclusions as to the changes brought about by time, until the results of the continued experiments after more prolonged intervals of time are at hand.

The effect of *heating* the cold-drawn bar at various temperatures may be seen by comparing the Diagrams 11, 13, and 14. The former refers to the cold-drawn bar in its original state, the second to a portion of the same bar after three hours' reheating at 160° C., and the third to another portion after three hours' reheating at 230° C. Fig. 15 summarises the results obtained by plotting the temperatures of reheating as abscissæ, and as ordinates the maximum internal tensions ($+\sigma_{max}$) and the forces P in kilogrammes represented by the shaded areas in Diagrams 11, 13, and 14, lying on one side of the horizontal zero-line. The curve P illustrates the decrease in potential energy in the bar by reheating. From Fig. 15 may be concluded that reheating gradually relieves the internal strains, and that this effect

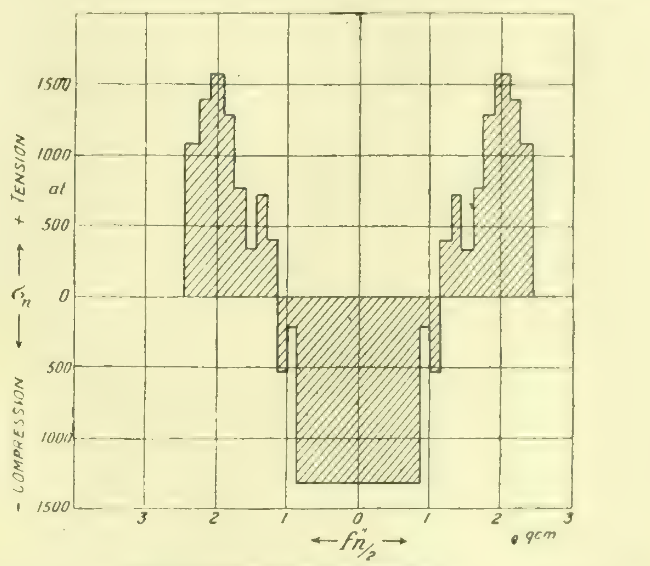


FIG. 11. ROUND BAR, COLD DRAWN.

Copper, 57·8 %; Zinc, 40·8 %; Lead, 1·35 %. Distribution of internal strain five days after the bar left the drawing plate.

becomes apparent much below the temperature limit t_r, at which the effect of cold-working (increase in tensile strength, increase of elastic limit, and decrease of elongation) is perfectly removed. According to the researches of Kudriumow (monograph of copper-zinc alloys) that limit t_r would, for the alloy under consideration, range from about 200° to 400° C. The specimens reheated for three hours at temperatures below 100° C. showed cracking when dipped in mercury solution, whereas specimens reheated three hours at 100° C. and more stood the dipping test without cracking.

The facts revealed by the experiments dealt with in the preceding paragraphs are of importance for the manufacturer of cold-drawn metals, since often specifications demand high amounts of tensile strength, which can only be obtained by severe cold-working, and since, on the other hand, too high a degree of internal strain must be avoided for the sake of the safety of the manufactured products.

In order to corroborate the effect of heating on cold-drawn metals, as shown above, I may be allowed to refer to experiments made with a steel round bar which had been reduced by cold-drawing from 41·5 mm. in diameter to 39 mm. (reduction of sectional area by about 12 per cent.). Reheating was effected for four hours at 100°, 200°, 300°, 400°, 450°, and 500° C., with subsequent slow cooling. The results of internal strain-measurements are somewhat irregular, since the cold-drawn bar evidently had been straightened in some unknown way, which gave additional strains arranged unsymmetrically to the axis of the bar, and varying over its length. Not-

* May lecture delivered before the Institute of Metals, May 12th, 1914.

† Royal Technical Institute, Charlottenburg, and Director of the Royal Prussian Institute for Testing Materials, Berlin-Lichterfelde.

withstanding this irregularity, the general effect of reheating may be seen from Fig. 16, in which the forces P being in equilibrium in the mass of the bar, and corresponding in some way to the amount of potential energy stored up in it, are plotted as ordinates to the reheating temperatures as abscissæ. The internal strains gradually decrease with increasing tem-

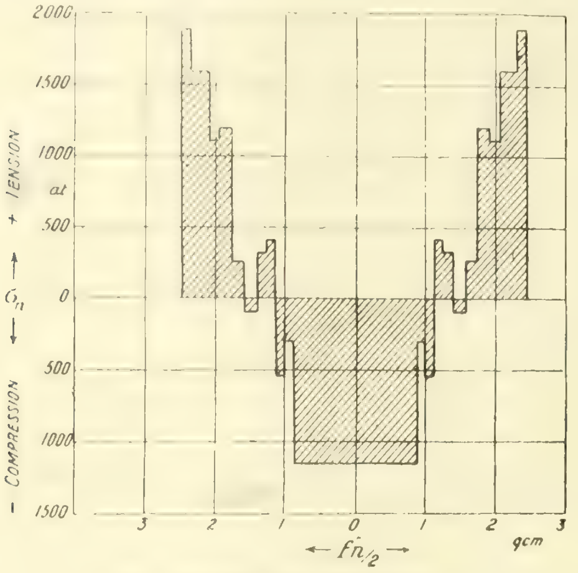


Fig. 16.—Round Bar, Cold-drawn.
Copper, 57·8 %; Zinc, 40·8 %; Lead, 1·35 %. Distribution of internal strain two years after the bar had left the drawing plate.

perature and reach a very low amount at 500° C., the temperature limit t_r for removing the effect of cold-working.

Some remarks may be devoted to the very serious question of the *spontaneous cracking* of cold-worked metals. This cracking often occurs without any perceptible cause, especially in cold-worked brass, aluminium-bronze, tin-bronze, high per cent. nickel-steel, and so on, if these metals are affected by severe internal strains. Cracking may occur long after they have been subjected to cold-working, sometimes years after-

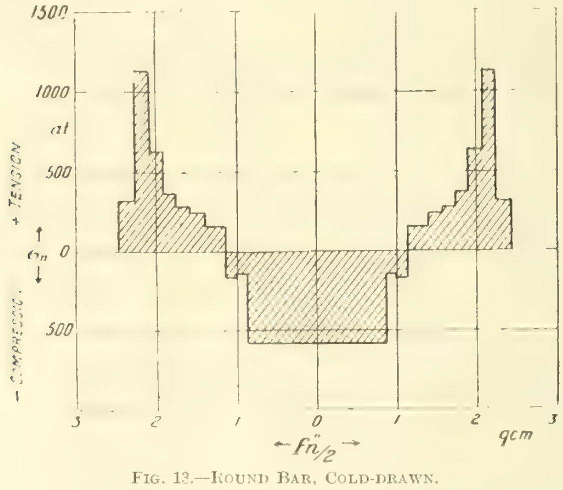


Fig. 13.—Round Bar, Cold-drawn.
Copper, 57·8 %; Zinc, 40·8 %; Lead, 1·35 %. Reheated three hours at 160° C.

wards; a phenomenon which, in the literature, is generally termed "season-cracking."

Thus, for instance, a cold-worked bar of aluminium-bronze is shown in Figs. 17 and 18. The composition of the alloy is the following:—

	Per cent.
Copper	88·2
Zinc	0·70
Iron	3·31
Aluminium	7·65
Phosphorus	0·028
Silicon	0·086

The internal strains were of such an amount that, after a certain time of storing the bar, transverse cracks developed spontaneously, penetrating to a depth shown in Fig. 18. What may be the cause of such cracking?

(*a*) It is obvious that additional stresses, due to the action of external forces, may in conjunction with the internal stresses reach such a degree that the ultimate tensile strength of the material is exceeded in certain parts of the mass, thus leading to cracking or partial fracture.

(*b*) Additional strains may be caused by unequal heating or cooling, thus producing the effect just mentioned. It is most probable that the cracking of the turbine blades pre-

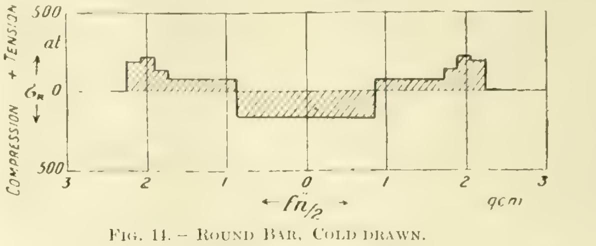


Fig. 14.—Round Bar, Cold-drawn.
Copper, 57·8 %; Zinc, 40·8 %; Lead, 1·35 %. Reheated three hours at 230° C.

viously referred to was due to this cause. As was shown, the blades were subjected to severe internal tensions at A, Fig. 5, that is, opposite to the side B, which is struck by the hot steam jet. When the blade passes before this jet there may for a very short interval of time exist a somewhat higher temperature at B than at A. This is equivalent to a sudden tension at A balanced by a corresponding compression of the material at B, thus causing additional temporary strains in the blade. Let σ_1 be the internal tension stress at A due to cold-working, σ'_1 the temporary additional stress due to difference of temperature; then the side A of the turbine blades will be subjected to often-repeated stresses between the limits σ_1 and $\sigma_1 + \sigma'_1$. As is generally known, this may involve cracking after a definite number of repetitions, provided the stresses σ_1 and $\sigma_1 + \sigma'_1$ exceed a certain limit.

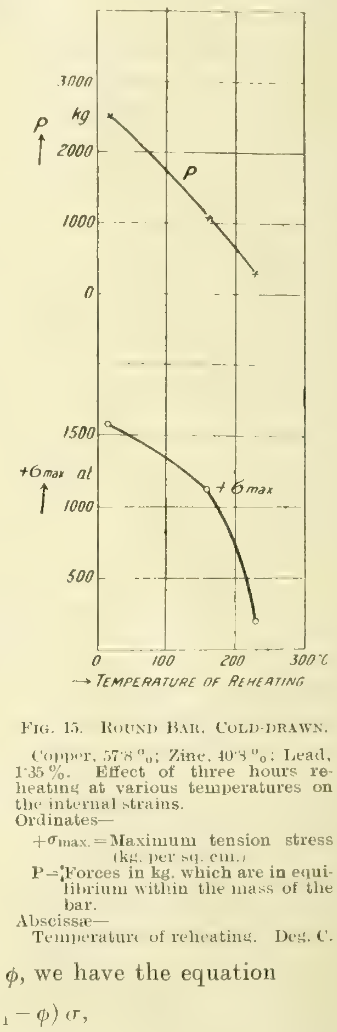


Fig. 15. Round Bar, Cold-drawn.
Copper, 57·8 %; Zinc, 40·8 %; Lead, 1·35 %. Effect of three hours reheating at various temperatures on the internal strains.
Ordinates—
$+\sigma_{max.}$ = Maximum tension stress (kg. per sq. cm.)
P = Forces in kg. which are in equilibrium within the mass of the bar.
Abscissæ—
Temperature of reheating. Deg. C.

(*c*) It is conceivable that scratching or other injury to the surface of cold-worked metals under severe internal strains may help the formation of cracks. Let σ_1 be the internal tension stress in the outer surface layer I of a cold-worked round bar in a longitudinal direction (Fig. 4), f'_1 the initial sectional area of this layer. If by local scratching at some point of the surface the sectional area of layer I be diminished by the amount ϕ, we have the equation

$$f'_1\sigma_1 = (f'_1 - \phi)\,\sigma,$$

where σ is the stress in the injured section $f'_1 - \phi$; consequently

$$\sigma = \frac{f'_1\sigma_1}{f'_1 - \phi}.$$

Relief of strains will not occur, since the length l, over which the strains are removed by the scratching effect, is only infinitesimal. On the contrary, according to the above equation the stress σ in the injured section will be increased. In addition to this the scratch acts like a notch, thus causing considerable local increase of stress intensity in the depth of the scratch.* If by this increase the ultimate tensile strength is reached, fracture may start from the scratch.

A very similar effect may be produced by corroding agents acting on the surface of cold-worked metals and giving rise to

* Notching effect: see Martens-Heyn, *Handbuch der Materialienkunde*, IIA, § 339-349.

local attack or pitting. (Uniform attack of the surface does not involve this effect, since it acts like removing the surface layer by turning and decreases internal strains.) The action of mercury and its solutions on certain alloys having strong internal strains has already been mentioned. In the case of cold-worked brass substances contained in the air, such as carbonic acid in conjunction with moisture, vapours of ammonia, of sulphurous acid, and so on, may, after sufficient periods of action, cause cracking.

It is no rare occurrence that condenser tubes of brass, which have been stored in the yard, without having been in service, suddenly show severe cracking, as illustrated, for instance, in Fig. 19. Their liability to cracking could be revealed by the fact that portions of the tubes still free from

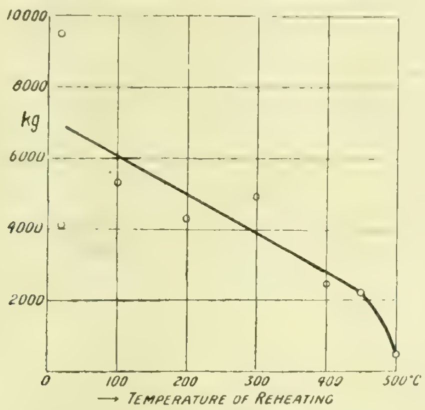


FIG. 16.—STEEL ROUND BAR, COLD-DRAWN.

Carbon, 0·29 %; Silicon, 0·08 %; Manganese, 0·98 %; Phosphorus, 0·031 %; Sulphur, 0·048 %. Effect of four hours reheating at the temperatures as abscissæ on the internal strains.

P = Forces in kg. which are in equilibrium within the mass of the bar.

cracks split up after being dipped in mercury solution.

The corroding effect may sometimes be a very unexpected one. For instance, a person painting brass tubes with cinnabar will not be aware of the fact that he is thereby endangering cold-drawn brass or bronze objects in a most serious way. To illustrate this, cartridge-cases were made of cold-worked brass, and at the mouths of these cases rather severe internal strains had been intentionally produced by cold-work. After painting them with a mixture of cinnabar and ordinary varnish, and after exposing them to the air in the presence of moisture, the cases split up at the mouth. The moisture acting on the mercury sulphide (cinnabar) in contact with the copper of the brass produced a slow chemical reaction forming sulphide of copper and free mercury. The latter exerted its effect on the cold-worked brass just in the same way as if the cases were dipped in mercury solutions. The

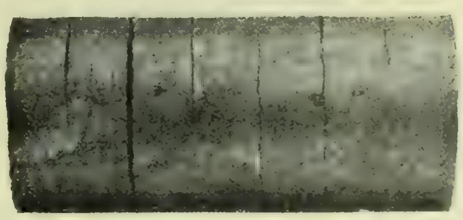


FIG. 17.

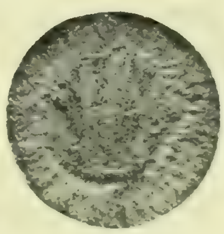


FIG. 18.

time in which this effect is produced is shorter the less the proportion of varnish in the paint. Without the presence of moisture the reaction is impossible.

A phenomenon observed in cold-rolled aluminium sheets must be recorded here, since it is due to similar causes. In certain kinds of water these sheets show, after some weeks' exposure, local bulging and blistering covered with white efflorescences, and they finally split up at some parts of their edges like a pack of cards, as may be seen in Fig. 20. The water has, in this case, played the part of the corroding agent, which by local attack and perhaps besides by some mechanical effect of the products of corrosion, produces strains in addition to the initial internal strains brought about by the process of cold rolling, so that finally local destruction occurs. The same sheets, exposed to the same kind of water after having been annealed, no longer showed the detrimental effect just described, since the internal strains due to cold working had been removed. This is shown by Fig. 21.

Touching the question of removing internal strains in cold-worked metals, some characteristic features have already been mentioned.

(*a*) Reheating at temperatures above the limit t_s, which removes all effects of the cold working on the strength pro-

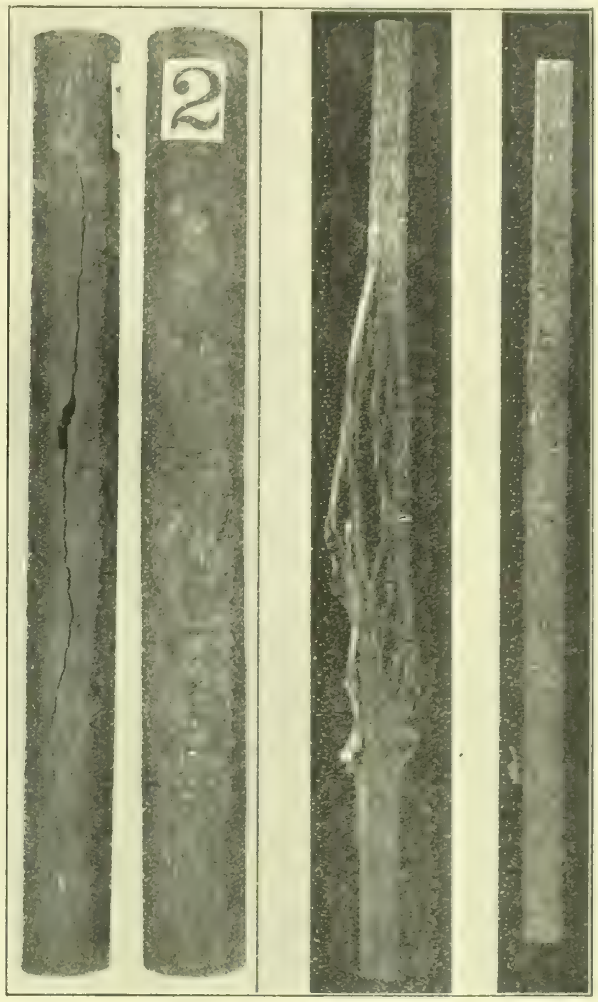


FIG. 19. FIG. 20. FIG. 21.

perties, at the same time eliminates the internal strains. As mentioned previously, remarkable effects towards diminishing the degree of internal strains can even be brought about at temperatures considerably below that limit.

(*b*) In the very process of cold-working it is possible to avoid the formation of dangerous internal strains by regulating the reduction in the different parts of the sectional area. For instance, in the case of the turbine blades in Fig. 5, it would be necessary to give a stronger reduction between two passes through the die at A than in the neighbourhood of the edges.

Since cold-rolling and cold-hammering are apt to produce tension strains in the core of the worked pieces, whereas cold-drawing, on the contrary, brings about tension strains in the superficial layers, it must be possible to diminish internal strains by alternate cold drawing and cold rolling.

(To be continued.)

Explosion at a Cement Works.—Six men were seriously injured in an explosion which occurred at the Aberthau Cement Works, near Barry, on the 26th ult. Following the explosion a fire broke out in the engine-room and buildings.

IMPELLERS FOR CENTRIFUGAL PUMPS, TURBINES, AND CONDENSERS.

THE accompanying illustrations show a construction of impeller for centrifugal pumps, turbines, condensers, and similar apparatus, the invention of The Rees Roturbo Manufacturing Company, Ltd., of Wednesfield Road, Wolverhampton, and its primary object is to reduce the weight and size and cost of construction without impairing the efficiency of the apparatus.

Fig. 1 is a central longitudinal section of a completely closed or shrouded impeller with part of the external casing, and Fig. 2 is a transverse section of the same partly on line A—A and partly on line B—B of Fig. 1 The impeller consists of a boss E carrying blades D, the sides of which slope

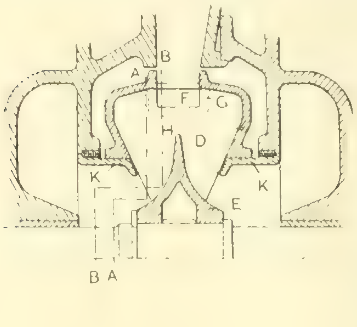


FIG. 1.

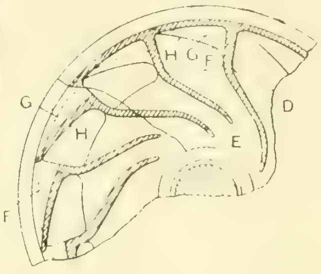


FIG. 2.

inwardly from the rim towards the eye. The peripheral discharge outlets F are formed within a trough extending around the periphery of the impeller, the side walls G of this trough forming the sides of the nozzle, while the outer and inner walls of the nozzles are formed by successive portions of the floor H of the trough which, as shown, is stepped so that the trough consists of a series of triangular portions each of a depth varying from zero or approximately zero at the lip of the discharge nozzle to a maximum at or near the point of greatest constriction of the nozzle. There are thus left on each side of the nozzle trough annular chambers of the full diameter of the impeller, wherein a mass of liquid at high pressure due to centrifugal force is stored. The inlets of the impeller are formed of the requisite diameter for the maximum output fixed by practice for a given impeller, and the fixed bush K of the casing is formed with a coned flange, the inner surface of which forms a continuation of the side wall of the impeller. This construction enables the effective aperture of the impeller eye to be varied simply by turning down the edge of the coned flange to a greater or less extent.

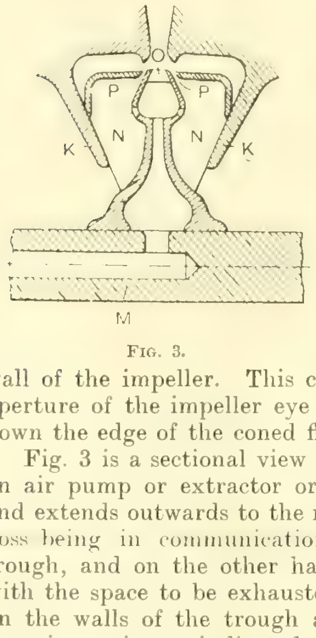


FIG. 3.

Fig. 3 is a sectional view of an arrangement applicable to an air pump or extractor or condenser. The boss is hollow and extends outwards to the nozzle trough, the interior of the boss being in communication on the one hand with the trough, and on the other hand through the hollow shaft M with the space to be exhausted or other gas or vapour space. In the walls of the trough are formed nozzles, arranged in opposing pairs as indicated at N, the jets of water issuing through which from the pressure reservoir impinge on each other at the centre of the trough so as to form flat or fan-like sheets of water or spray, the aspirating action of these sheets of sprayed water drawing gas or vapour through the hollow shaft and impeller boss, the entrained gas or vapour and entraining water being discharged into the vortex chamber or expanding ducts of the fixed casing, this action being assisted by short transverse blades O fitted across the outer edge of the trough which act as an extractor. The final compression is effected by the streams of water discharged from the pressure tank on each side of the nozzle trough through the two annular slits P (or two rings of nozzles) formed between the walls of the trough and those of the pressure tank.

THE TALBOT PROCESS IN COMPARISON WITH OTHER OPEN-HEARTH REFINING PROCESSES.*

BY DR. FRIEDRICH SCHUSTER (WITKOWITZ).

THE Witkowitz Ironworks, established in 1829, have in the course of time employed a number of processes of steel manufacture. The reason for this is to be sought for partly in the changes in the sources of raw material supply, and partly on account of actual technical progress. The acid process, introduced in the year 1867, had to be abandoned owing to the difficulty of obtaining non-phosphoric ores, and was replaced in 1879 by the basic process. This, again, was finally replaced in the year 1882 by the well-known duplex process, which had its origin and development in Witkowitz. As auxiliary to this last process, the most diverse modifications of the open-hearth process on a basic and acid hearth were employed.

Although from a qualitative point of view the results of the duplex process were perfectly satisfactory, and, in comparison with other systems, the output of the various furnaces was considerable, the cost of production of the steel caused by the necessity of carrying out the manufacture in two separate apparatus (the Bessemer converter and the open-hearth furnace) was so high as to render it necessary, for some considerable time past, to consider the question as how best to replace the expensive duplex process by a cheaper method of steel manufacture.

Owing to the conditions of the ore supply, it was not possible to change over to the basic process, which is to-day undeniably the cheapest process of steel manufacture. Owing also to the relatively high total production, the introduction of the scrap process was out of the question, since the quantities of scrap necessary for working the process were not obtainable at sufficiently low prices. There thus remained only the pig-iron ore process as a possible practical solution. Various experiments undertaken in this direction gave results, however, which were not sufficiently favourable to admit of an entire change of the previously satisfactory methods being contemplated.

The solution of this difficult problem was, however, a matter of considerable urgency, the time having arrived to consider the complete reconstruction of the rolling-mill plant, which had become, in part, antiquated. As in all old works, difficulties on account of space caused the original plan of a reconstruction of the steel and rolling-mill plant on the existing site to be abandoned, and necessitated the re-erection of the plant on a site distant about one and a half miles from the old works, so as to allow for possible future expansion.

The following fundamental points were taken into account in designing the new plant: (1) Introduction of a steel process which, in addition to admitting of the possibility of manufacturing the most diverse qualities of steel, would ensure the lowest costs of production, taking the local conditions into account. (2) The entire exclusion of steam power, and its replacement by electrical energy with a view to utilising the surplus gases from the blastfurnaces and coke ovens. (3) Selection of a site permitting of future extensions in the various departments. (4) Shortest transport of material from the raw product to the finished goods, without hindering the normal working of the individual departments. (5) The adoption, wherever possible, of travelling cranes for the transport of the intermediate products, and leaving the ground and the space between the various rolling-mills as free as possible for the work of rolling proper. (6) Uniform floor level for all departments. (7) Easy accessibility to all moving machine parts from the floor. (8) Replacing manual labour as far as possible by mechanical equipment in dangerous metallurgical operations.

After fully considering the above points, the result was the plant now in use, which comprises: An annular lime furnace and dolomite plant for the purposes of the steelwork; the track for conveying the raw material, terminating in an overhead railway provided with bunkers for all kinds of raw material; a producer plant, comprising 20 Kerpely producers, for generating gas for all metallurgical and reheating

* Paper read before the Iron and Steel Institute, May, 1914.

furnaces; store-yard, traversed by magnetic travelling cranes, for scrap and solid pig iron; steelworks plant; reheating furnace building; cogging mill.

By the side of the latter is the large transformer station for the reversing rolling mills, which are driven by direct current. In the rolling-mill buildings are housed a total of 15 trains of rolls, namely, 1 armour plate rolling mill, 3 sheet rolling mills, 2 universal mill trains, a reversing billet mill, having rolls 850 mm. diam., a rail and girder train of the same diameter of rolls, a 600 mm. three-high breaking-down mill, and the medium and small mill trains.

At a right angle with the cogging mill runs a distributing shed, in which travelling cranes convey the rough rolled material, cut into suitable lengths, to the various trains of rolls to be worked up direct; or they pass it to the reheating furnaces, whence they are taken to be finished in the various mills.

Perpendicular to the rolling-mill houses are the buildings for containing the hot banks and straightening appliances, the latter communicating with each other by three large transepts. Connected with this entire system of buildings are the stores for rails and girders, with their corresponding cold-

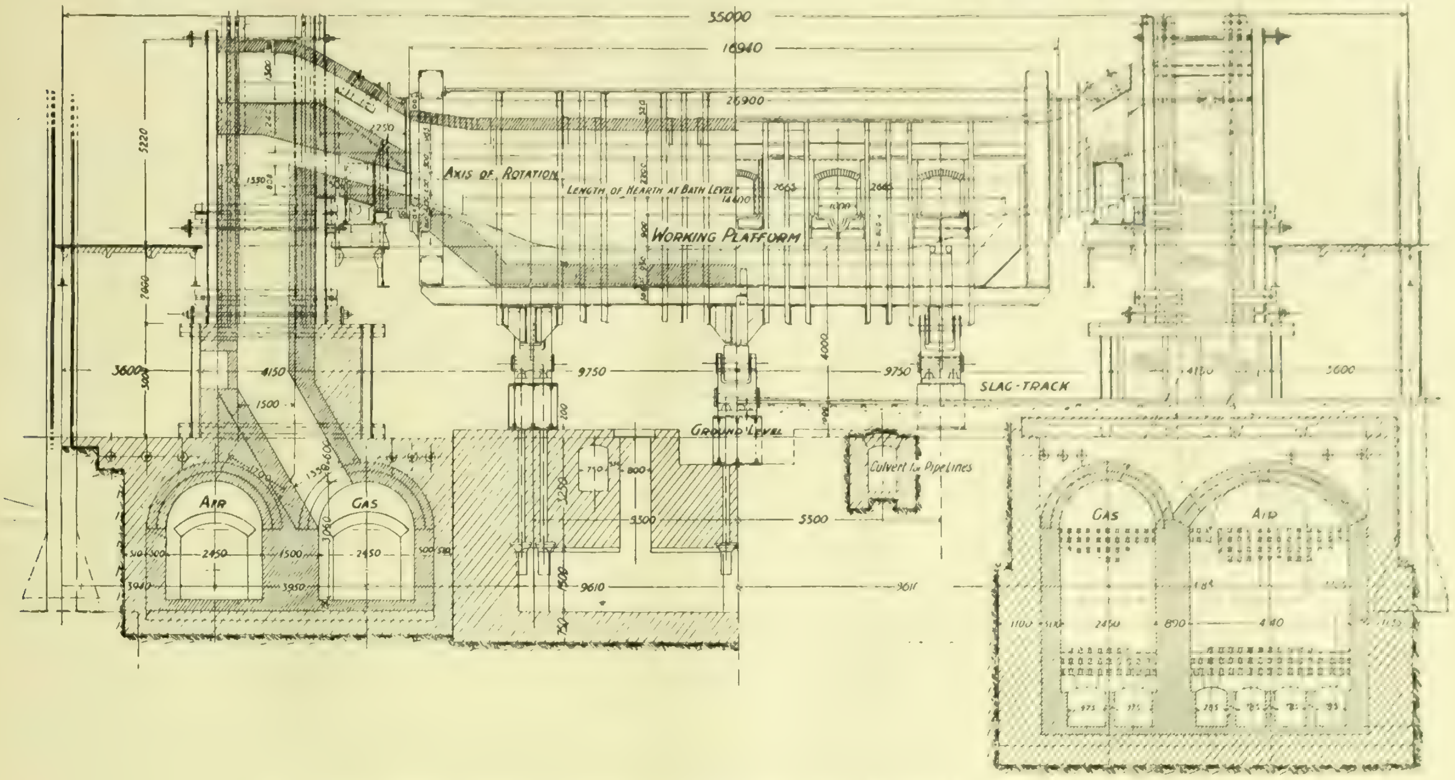


FIG. 1. LONGITUDINAL SECTION AND ELEVATION OF A 200-TON TALBOT FURNACE AT WITKOWITZ IRONWORKS.

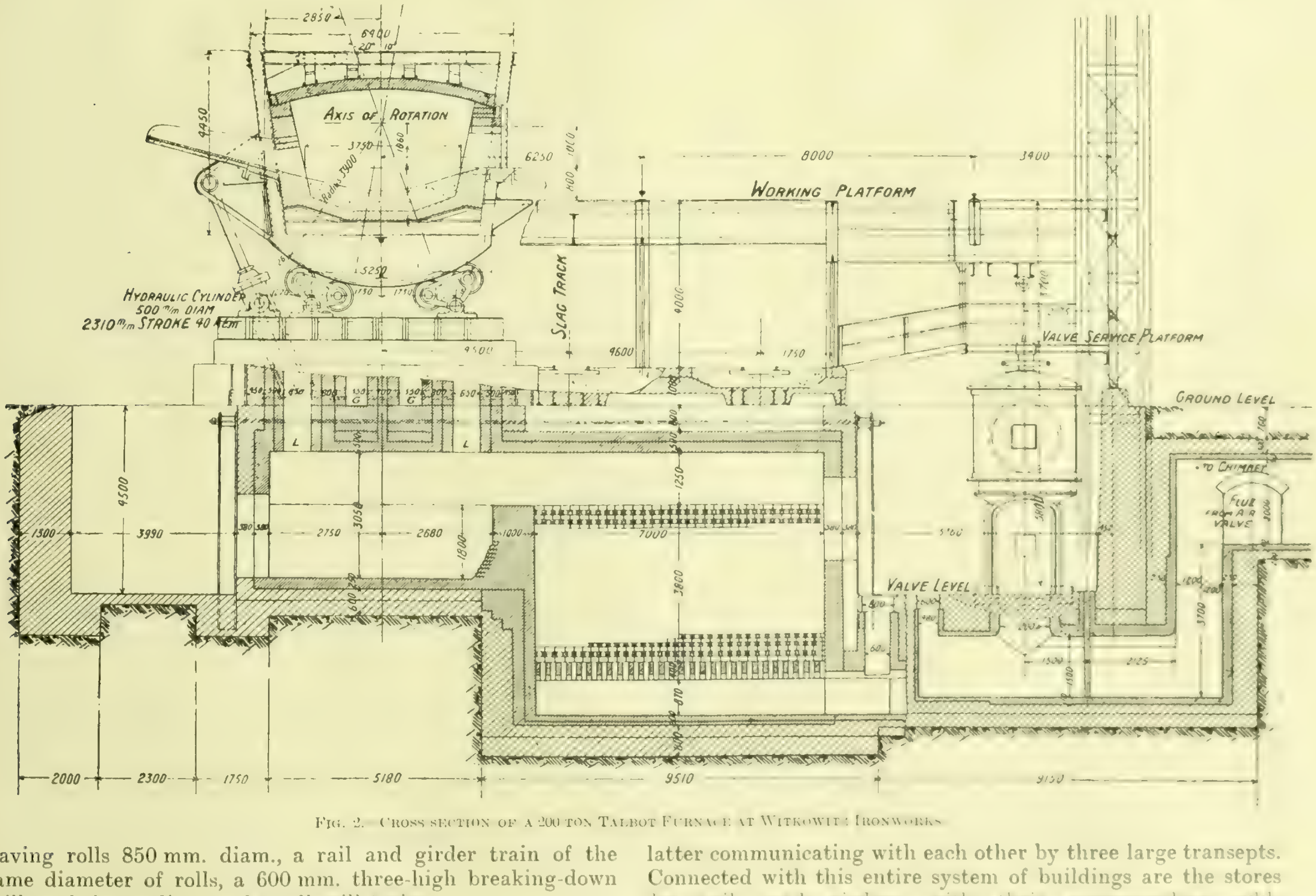


FIG. 2. CROSS SECTION OF A 200 TON TALBOT FURNACE AT WITKOWITZ IRONWORKS

straightening plant, and also the bar-iron bank. The entire plant is completed by various auxiliary workshops, a roll-turning shop, smithy, fitting shop, administration buildings, laboratories, workmen's dining-hall, and bathrooms, &c.

To give some idea of the extent of the new plant, it may be mentioned that the entire steel and rolling-mill plant has a covered area of roughly 105,000 square metres, and that, in addition, various store yards of 45,000 square metres area are served by crane tracks, so that the total covered area may be taken, in round numbers, as 150,000 square metres.

As will be seen from the previous statement of the number of rolling-mill trains, we have to deal in Witkowitz with a very considerable programme of rolling operations, in connection with which it must be mentioned that, having regard to the limited market, only relatively small quantities of each individual type of rolled goods can be produced; while, on the other hand, the rolling mills have to supply diverse qualities of ingot iron and steel. The prospective steelworks had therefore to be adapted to specific Austrian conditions, which do not render possible a bulk production in the sense of the large West German ironworks, but necessitates the manufacture of a multiplicity of products, by which alone we are enabled to attain a production equal to that of a medium-sized ironworks in Germany. Taking these circumstances into account, the proper selection of the most suitable steel process offers real difficulties.

The steel process to be selected had to possess the possibility of producing any desired quality of steel, individual charges being carried out in quick succession, and, further, of using, as scrap, the waste produced in the work of rolling. A further natural assumption was the necessity of producing, at as low a cost as possible, a pig iron of medium phosphorus content suitable for the production of the finished steel, such as would be produced on the basis of the conditions already laid down.

With a view to solving this question, we devoted a considerable amount of time and study to all previous forms of reverberatory furnaces; and it is my pleasant duty at this stage to offer our cordial thanks to all steel and iron companies who granted facilities for a thorough inspection of their plant with this object in view. The longer and more profoundly we considered the question, the more we recognised that a process which, in the case of a particular steelworks, gave perfectly satisfactory results from a qualitative point of view, as well as showing favourable figures for the cost of production, could not at once be applied where entirely different conditions prevailed. The directly contradictory opinions concerning one and the same process carried out in different localities are generally based on the difference of the costs of production for pig iron and in the price of scrap. Mr. N. Schock has already referred to this point in his interesting paper, read at the general meeting of the "Sudwest" Ironworks, on February 15th last, on the economy of the open-hearth process in comparison with the basic process. I will refer in more detail to this paper later on.

As a result of our preliminary investigations, we soon arrived at the conviction that, for Witkowitz, the pig-iron-ore process was the only one possible, and it was now a question of determining whether it would be more satisfactory to work with fixed or tilting open-hearth furnaces. Favourable reports were to hand from England and America concerning the use of tilting furnaces; but a difficulty was raised by the fact that, in spite of the gradually increasing production of open-hearth steel in Germany, this type of furnace was now practically nowhere employed. Apart from the undoubtedly higher initial cost of a tilting furnace compared with one of the fixed type of the same capacity, the relatively higher maintenance costs of the former type, and the higher expenditure of fuel, were cited as against this type of furnace.

With regard to the Talbot process—only practicable in tilting furnaces—a fact in its disfavour was that (apart from America and England) it had not been able to find a footing in the other steel-producing countries, in spite of various reports upon the favourable results obtained with it; this was all the more surprising since the first 75-ton Talbot furnace was put into operation at Pencoyd, U.S.A., in the year 1898. On the Continent, the Senelle Ironworks in France was the only establishment which, up to 1906, had begun to produce steel in a 175-ton Talbot furnace. This furnace, however, was in 1908 again shut down.

In spite of these by no means encouraging facts, we decided to make an exhaustive investigation of the Talbot process and its application to our conditions; and with this object our steel experts made repeated visits to England and America, and also to Senelle. We were not able, however, as the result of those visits, to come to a definite decision, inasmuch as in each of the plants inspected fundamental differences existed between their conditions and ours, partly as regarded the composition of the pig iron employed, and partly as regarded the quality of the products produced. Another fact that rendered our decision more difficult was that practically everybody offered conflicting opinions and advice as to carrying out the process. It was a matter of considerable surprise to us that an American works, which had installed a number of Talbot furnaces, had reintroduced in a second plant the duplex process, which we had found too expensive, and wished to replace by some other process.

A very considerable objection to the introduction of the Talbot furnace consisted in the relatively great length of hearth, which considerably exceeded the dimensions hitherto usual with us, and made us apprehensive as to whether it would be possible to obtain uniform heating over the entire surface of the bath with the short-flamed Ostrau coal at our disposal. (This fear has happily proved to be unfounded since we adopted the large furnaces). In order to arrive at as sound a judgment as possible on the Talbot process, we asked Prof. Eichhoff, conjointly with Mr. von Maltitz, again to visit all the English Talbot plants, and, on the data placed at their disposal, to give an expert opinion. This was in favour of the adaptability of the Talbot process, with certain important modifications, to meet our local conditions. As the result of all our studies we recognised that we would have ourselves to elaborate the most suitable process for our conditions, employing generally recognised principles, and arrive at the basis of the final arrangement of our steelworks by large scale comparative experiments.

We have already mentioned the distance of the new steelworks from our blastfurnace plant, and this fact rendered it desirable at the outset to provide a pig-iron mixer, which, in view of the prospective daily production of 800 tons of steel, could only take the form of a mixer capable of being heated. Since we were confronted with the necessity of providing a second mixer sooner or later in view of the future development of the plant, and for the purpose of having the necessary stand-by, it was found possible for us, by simultaneously installing two 300-ton (heated) tilting furnaces, to use one as a pig-iron mixer and the other as a Talbot furnace, and, in case the Talbot process should give unfavourable results, to use the latter as a second mixer. The higher capital cost of the new steelworks necessitated by this assumption had also to be taken into account.

Since we, moreover, entertained certain doubts as to whether the Talbot process would at once be suitable for manufacturing different qualities of steel in rapid succession from charge to charge, we decided, as a precaution, on the construction of three fixed, 50 to 60-ton open-hearth furnaces for the purpose of simultaneously melting the scrap from the rolling mill. For the purpose of estimating the difference between fixed and tilted furnaces of the same capacity, a 60-ton Wellman (tilting) furnace was also installed. To complete the whole, a small electric steel plant comprising two furnaces of 2 and 6 tons capacity was arranged for, the smaller serving as a furnace for remelting ferro-manganese and the larger for the manufacture of special qualities of steel.

The producer plant, comprising 20 Kerpely producers, has an automatic ash ejector and a conveyer belt traversing the entire plant, which empties the falling ashes into a collecting pit situated at the end of the building, whence the ashes are loaded into wagons by the grab cranes. In the producer building two Garbe water-tube boilers, each having a heating surface of 220 square metres, are erected, these boilers being the only steam generators in use in the entire

steelworks and rolling mills. In the winter months the steam necessary for heating a number of rooms was taken from the small steam generating plant.

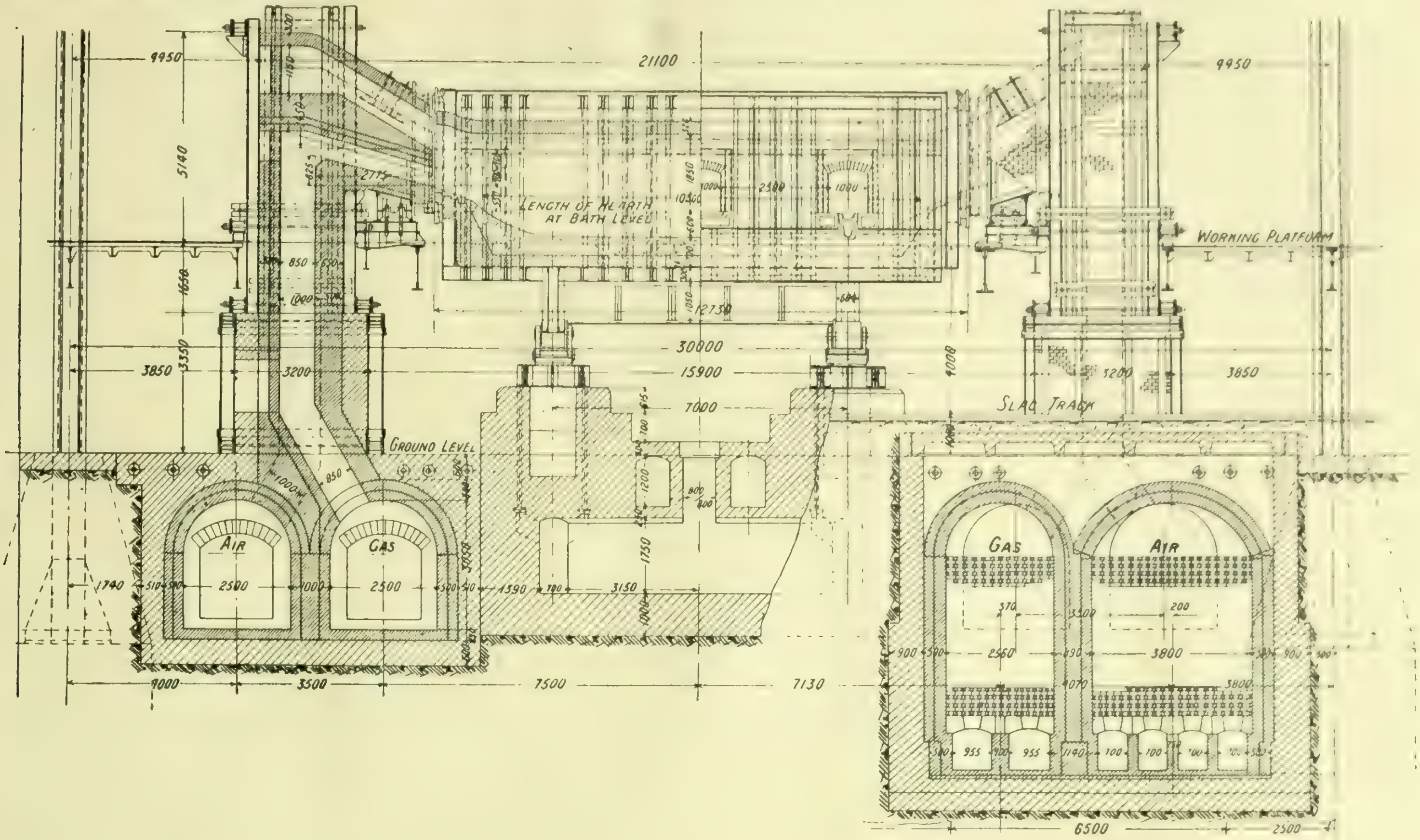


Fig. 3.—Longitudinal Section and Elevation of a 50 to 60-ton Tilting Furnace at Witkowitz Ironworks.

To enable the consumption of fuel for each individual system of furnace to be determined in a reliable manner in the comparative experiments which were made, the producer plant was arranged so that a particular group could be worked exclusively on one furnace; but the initial number of producers had to be somewhat increased, of course, in order to provide the necessary reserve for each individual group. Since, however, all the producers deliver into one masonry gas main, it was possible to secure the desired object by

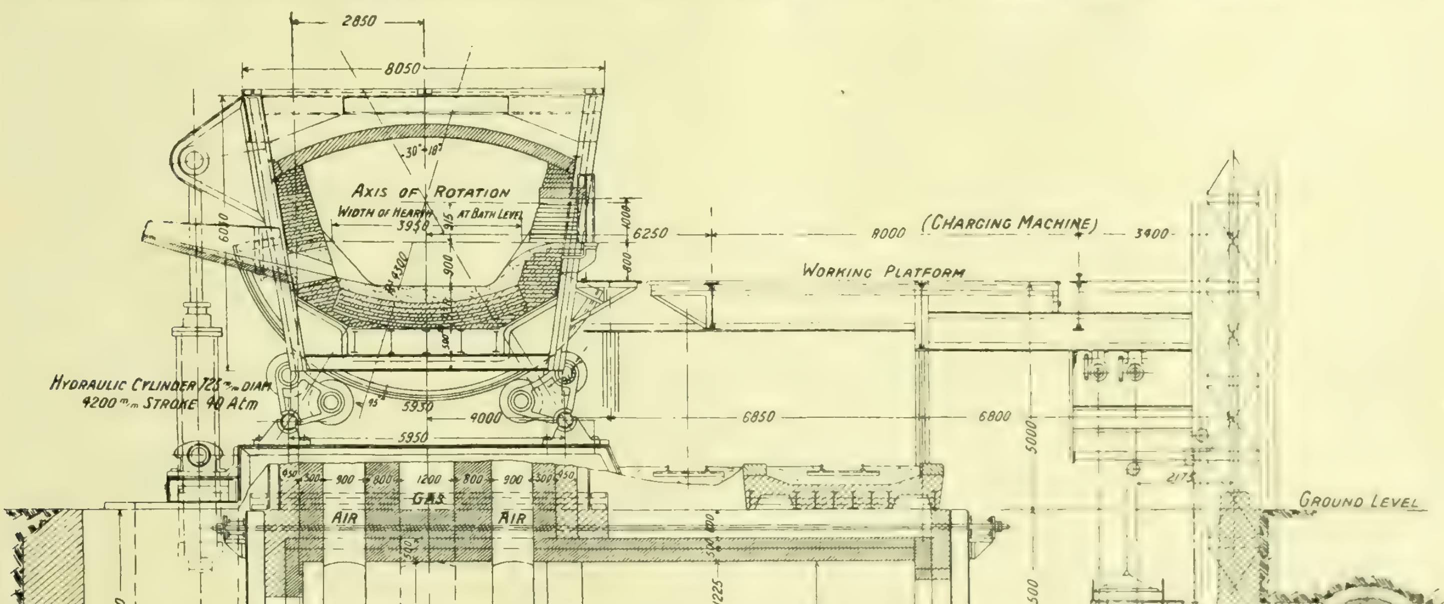


Fig. 4.—Cross-section of a 50 to 60-ton Tilting Furnace at Witkowitz Ironworks.

introducing partition walls in the main, which could be removed later when the separate working of the producer group was no longer required. In order to obtain the required reserve it was only necessary to add to the original number of producers installed the number which had in any case been provided for when planning extensions. Outside the producer building, under a working platform of 8 metres width, are situated the purifiers, consisting of cylindrical retorts lined with masonry, in which the preliminary operation of separating the dust and tar is carried out. Underneath the purifying chambers, provided with water seals, an electrically-driven truck runs in a trough in which the dust from each purifier is emptied into this wagon and deposited in a separate dust pit at the end of the plant. Between the producer plant and the steelworks building is the stockyard for scrap, pig iron, and ore, these stocks being traversed by two magnet cranes and two travelling cranes. The charging boxes are filled here, being taken up by the crane travelling on the side wall of the steelworks building and brought to the charging platform, where they are taken over by the charging machines.

The steelworks building proper comprises two houses, each of 20½ metres span, and a total length of, roughly, 200 metres, in one of which the furnaces, with the working platform, and in the other, the casting platforms and ladle shop, are installed. In the furnace-house are installed, as has already been stated, two large tilting furnaces of nearly similar construction, the only difference being in their capacity, owing to the difference in lining. Whereas the furnace used as a mixer (capable of being heated) holds 300 tons of liquid pig iron, the Talbot oven is lined so as to hold 200 tons.

As may be seen from Table I., both furnaces have a length of bath of 14,400 mm.; and in the Talbot furnace (Figs. 1 and 2) a breadth of bath of 3,950 mm., and in the mixer of 4,500 mm.; a depth of bath of 900 mm. in the Talbot furnace, and 1,070 mm. in the mixer, the total length of the tipping frame being 16,940 mm. The other dimensions may be seen on reference to the drawing.

In distinction to the type of furnace largely used in England, with removable ends, our two tilting furnaces have fixed, interchangeable ends on the Friedrich system, between which the hearth can be moved, by hydraulic cylinders, about an axis passing through the centre of the two gas ports, an arrangement offering considerable advantages. All cooling rings, as well as doors and door frames, are water-cooled, and the doors, chimney dampers, and reversing gears are driven by electric motors.

The tilting Wellman furnace (Figs. 3 and 4) has a length of bath of 10,500 mm., a width of 3,750 mm., and a depth of 600 mm., and holds 60 tons. The three fixed open-hearth furnaces have a length of bath of 10,000 mm., a width of 3,600 mm., and a depth of bath of 700 mm. The regenerator chambers for the preliminary heating of gas and air are situated somewhat to the back towards the working platform, and all have easily accessible slag pockets. This arrangement has necessitated the regenerator chambers being built to lie somewhat low, giving somewhat longer uptakes.

The Talbot furnace has one inlet port for gas and one for air, while the Wellman furnace and the fixed open-hearth furnaces each have two inlet ports for gas and air—an arrangement which, on any future reconstruction, we should modify so as to secure uniformity with the Talbot furnaces. All furnaces have interchangeable ends, constructed on the Friedrich system. The chimneys for the two large tilting furnaces are 55 metres high and 2·135 metres in internal diameter; those for the four other furnaces are 55 metres high and 2 metres internal diameter.

On the working platform, behind the furnaces, run two electrically-driven charging machines, and above them, two 50-ton travelling cranes for the transport of pig iron and mixer iron, each of these having a 15-ton auxiliary crab. The casting house (Fig. 5) is traversed by two 80-ton casting cranes, each having a 20-ton auxiliary crab; while, on a second track, situated at the higher level, is a 50-ton crane provided with a 15-ton auxiliary crab. In addition, for transporting lesser loads, various bracket travelling cranes are installed.

TABLE I.—*Comparison of Furnaces.*

Furnace.	Dimensions of Hearth*.			Capacity of Chamber for each Half of Furnace.†		Average Weight of Charge.	Daily Production with Pig Iron containing‡		Production per Square Millimetre Hearth Area with Pig Iron containing‡		One Ton of Steel is produced with Pig Iron containing‡				Kilos of Slag per Ton of Yield; Pig Iron containing‡		Total P_2O_5 of the Slag; Pig Iron containing‡		Per cent., Chemical combined Iron in the Slag.
	Length.	Width.	Area.	Gas.	Air.		1·1 per cent. P.	1·7 per cent. P.	1·1 per cent. P.	1·7 per cent. P.	1·1 per cent. P.		1·7 per cent. P.		1·1 per cent. P.	1·7 per cent. P.	1·1 per cent. P.	1·7 per cent. P.	
	m.	m.	m†.	m‡.	m‡.	Tons.	Tons.	Tons.	Tons.	Tons.	Mins.	Secs.	Mins.	Secs.	Kilos.	Kilos.	Per cent.	Per cent.	Per cent.
Talbot	14·4	3·95	53·8	68	115	65·6	320	295	5·94	5·48	4	30	4	53	155	187	15·1	19·1	Circular 9
Wellman ..	10·5	3·75	36·4	68	101	62·8	200	175	5·49	4·81	7	12	8	13	200	250	10·9	13·2	Circular 9·5
Open-hearth	10·0	3·60	33·0	68	101	55·7	170	150	5·15	4·54	8	30	9	36	175	210	11·2	14·2	Circular 10·5
Mixer	14·4	4·50	61·0	68	115	ca. 30	450	500	ca. 8		—	—	—	—	—	—	—	—	Circular 6

* Hearth dimensions at height of bath with an average charge. Width = maximum width.
† Chamber capacity, *i.e.* the part of chamber filled with bricks = capacity of chequer work + spaces.
‡ Assumed: Talbot with 5 per cent. scrap, Wellman with 13 per cent. scrap, Open hearth with 25 per cent. scrap } and using mixer iron.
The mixer production is entirely dependent on charge and output of pig iron.

The working procedure is as follows: The pig iron is brought to the steelworks from the blast furnaces, situate at a distance of rather less than 1½ miles, in standard gauge ladle trucks each of 30 tons capacity. These ladles are thoroughly pre-heated with blastfurnace gas, and after filling are closed with a cover lined with refractory bricks, thus obviating (1) spurting of the material during the relatively long journey; (2) any large amount of cooling of the pig iron even when the full ladles are left standing for some hours.

The pig-iron ladles are first brought into the steelworks casting house, and, on the lid having been removed, they are hoisted up by the 50-ton crane and placed on a bogie on the working platform between the mixer and the Wellman furnace, which runs between the casting house and the furnace house. The 50-ton crane in the latter house takes over the ladles, emptying their contents into the mixer through one of the openings in the door (Fig. 5). The mixer, before introducing the pig iron, is charged with about 3·5 per cent. ore and about 1 per cent. limestone.

As a result of experiments, it has been found to be most advantageous to use the mixer chiefly as a collecting vessel,

without carrying out in it—as is done in a number of works—any considerable amount of refining. Although, for the purpose of making the hearth linings of the open-hearth

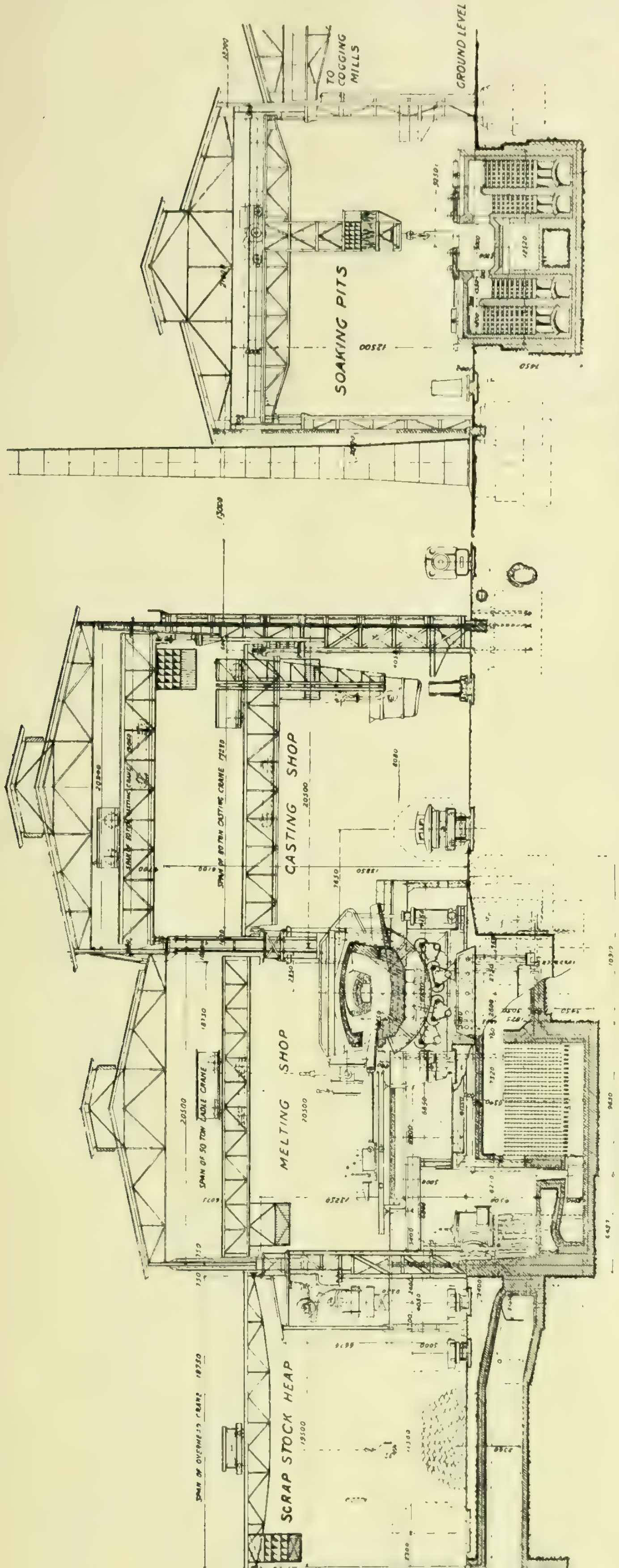


FIG. 5.—ELEVATION OF SCRAP, MELTING, AND CASTING SHOPS AND SOAKING PITS AT THE NEW STEELWORKS, WITKOWITZ.

furnaces last as long as possible, we employ pig iron containing, on the average, below 1 per cent. of silicon, we always attempt, as far as possible, to remove this latter impurity in the mixer, which is done without difficulty. The function of keeping down the sulphur content of pig iron as much as possible is fulfilled by the mixer all the more easily since we were able to ascertain by numerous experiments that in some cases up to 50 per cent. of the original sulphur content can be removed during the transport of the pig iron in the ladles. Taking the mean of an extensive series of experiments, it was found that the average decrease of the sulphur in the pig-iron ladles was 36·5 per cent., and of the manganese 12·06 per cent.

Since with the type of ladle selected no appreciable scale is formed even when the liquid pig iron is kept in the ladle for a number of hours (individual ladles were allowed to stand for four hours for the purpose of the experiments), the work can be arranged so that, according to the requirements of the open-hearth furnaces, mixer iron can be taken, after which the operation of refilling with fresh pig iron is carried out. Table II. shows the average composition of the pig iron used in our various experiments, as also the average composition of the mixer iron and mixer slag relating thereto.

TABLE II.—*Average Analyses.*

(*a*) Pig Iron.				(*b*) Mixer Iron.			
Mn. per cent.	Si. per cent.	P. per cent.	S. per cent.	Mn. per cent.	Si. per cent.	P. per cent.	S. per cent.
2·11	0·83	0·55	0·07				
2·09	0·72	0·77	0·06	Mixer not in operation			
1·82	0·54	0·97	0·07				
1·67	0·69	1·08	0·06	0·94	0·21	1·07	0·04
1·57	0·69	1·51	0·07	0·97	0·25	1·48	0·04
1·56	0·56	1·74	0·07	0·86	0·17	1·67	0·03

(*c*) Mixer Slag.

With a Pig Iron containing	SiO_2 per cent.	P. per cent.	Fe. per cent.
P = 1·1 per cent.	29·92	1·78	5·99
P = 1·7 per cent.	29·60	1·96	4·51

The quantity of liquid pig iron dealt with in the mixer in 24 hours is roughly 500 tons, thus giving an average daily production per square metre of about 8 tons, with a hearth area of 61 square metres. The following average charge was employed per ton of mixer iron:—

	Kilos.
Pig iron, liquid	967
Pig iron, charged cold	29
Ore	35
Limestone	10

Since the start on May 10th, 1913, 150,000 tons (roughly) have been produced during the entire working period, the average fuel consumption being 60 kilos per ton. The yield obtained is approximately 100 per cent. Up to the present no appreciable repairs have been necessary to the mixer lining, and we still anticipate, in view of the present state of preservation, carrying out a fairly considerable number of heats.

In order to be able to introduce the liquid pig iron from the blastfurnaces into the mixer, even in cases in which for some cause the standard gauge track leading into the steelworks casting house cannot be used, or, in the event of the 50-ton pig-iron crane sustaining any damage, the ladle trucks can be brought on an auxiliary line directly below the working platform of the furnace house, whence the ladle would be taken over by one of the 50-ton travelling cranes.

As has already been pointed out, we endeavour as far as possible to reduce the amount of refining carried out in the heated mixer, such work being mainly confined to the oxidation of the silicon and a portion of the manganese, in which, incidentally, considerable desulphurisation of the pig iron takes place. The main advantage of the mixer is, from our point of view, that it is perfectly independent of the working of the blastfurnaces, in that the finishing furnaces always

have at their disposal, without any waiting, the quantity of mixer iron which they require with a uniform chemical composition. The increase in production of the steel furnaces since the mixer was put into operation has been found to be roughly 30 per cent. At the same time, however, it is always possible to melt certain quantities of cold pig iron and even scrap in the mixer without any appreciable increase in the fuel consumption. The mode of operation of the finishing furnaces is, of course, different in the case of the Talbot furnace than in the case of the Wellman tipping-furnace and the fixed open-hearth furnaces.

(To be continued.)

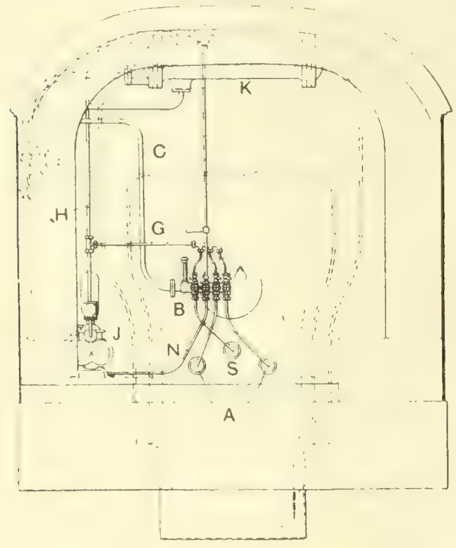


Fig. 1.

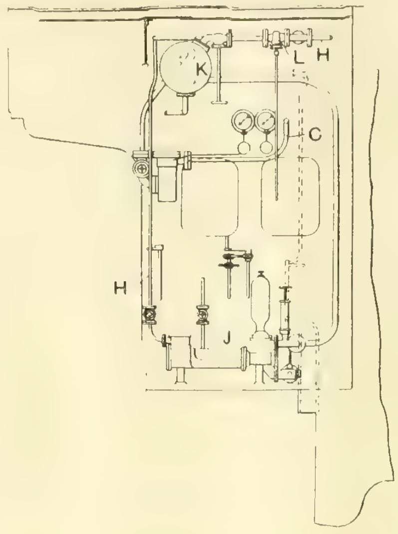


Fig. 2.

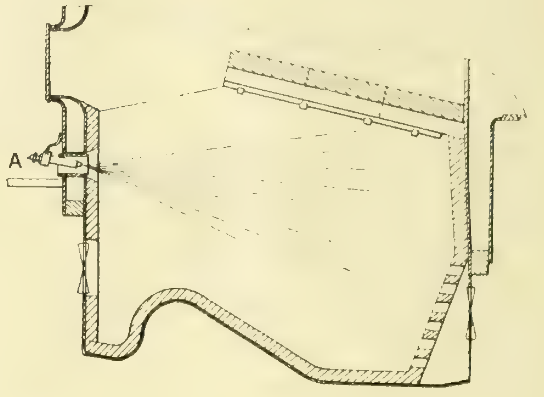


Fig. 3.

Liquid Fuel Burning System for Locomotive Boilers.

LIQUID FUEL BURNING SYSTEM FOR LOCOMOTIVE BOILERS.

A system of oil burning applicable to locomotive boilers has recently been designed and patented by Mr. Andrew Laing, of 15, Osborne Road, Newcastle-on-Tyne. This is shown in the cuts herewith, of which Figs. 1 and 2 show the general arrangement, Figs. 3 and 4 longitudinal sections of the furnace, showing different dispositions of the fuel burners, and Fig. 5 the distributing valve box. The firebox, which, together with the bridge, has a lining of refractory material, is provided with a number of oil burners to which the oil is supplied through a distributing box B from a pipe C. The distributing box is provided with an emergency cock D which, in one position, admits oil to the burners A, while in another position it cuts off the oil supply from these burners and at the same time admits steam through the valves E to the burners A, thereby blowing out any oil and preventing carbonisation of the same. The steam is also delivered to the blow-through cocks F by pipe G, which branches off from the steam supply pipe H to the oil pump J, and these cocks are fitted so that steam can be admitted to any one burner for the purpose of clearing that particular burner of oil, independently of the remaining burners. The oil fuel pump draws oil from a tank or reservoir which may be situated in the engine tender and connected with the suction inlet of the pump by a flexible pipe and delivers the oil to a heater K and thence through a filter to the supply pipe C leading to the distributing box. Steam is supplied to the pump J through pipe H, from which latter pipe branch leads to the heater K through a regulating cock L, actuated by a lever simultaneously with the emergency cock D, so that when the oil supply is cut off from the burners A the steam supply to the heater is correspondingly reduced. In addition to the valves mentioned the various parts of the apparatus are provided with manually-operated regulating or shut-off valves,

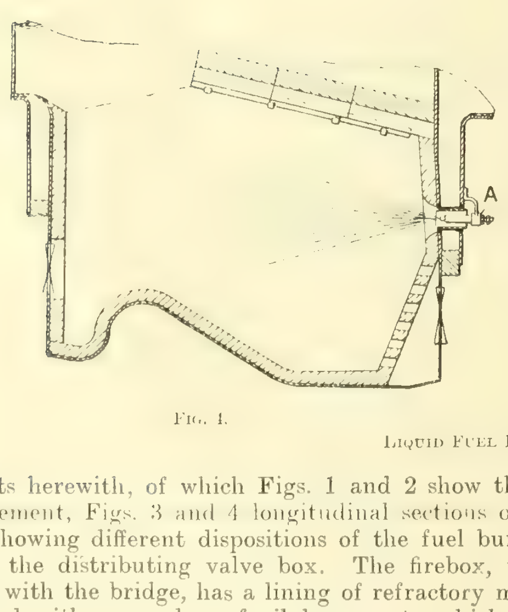


Fig. 4.

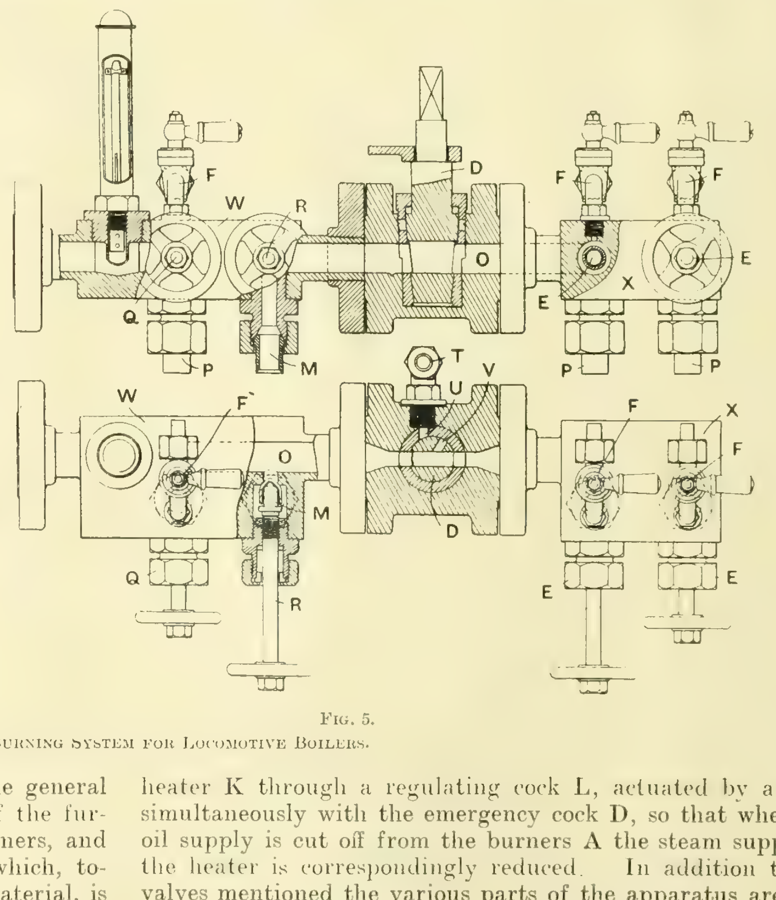


Fig. 5.

Liquid Fuel Burning System for Locomotive Boilers.

and one or more pressure gauges are also fitted to show the oil pressure at one or more points of the installation.

The distributing box B, in addition to delivery to the burners, also delivers through a by-pass valve M to a pipe N leading to the suction side of the pump so as to maintain a circulation of oil when the emergency cock is turned to cut off the main burners. This by-pass, like the burners themselves, is fitted with a regulator controlling the flow of oil therethrough. The valve-box body is divided into two portions W and X by the emergency valve D, the portion X being connected to the burners A adapted to be cut off simultaneously by the emergency valve D. The other portion W is connected by a flange joint with the oil supply pipe C. A main oil channel O runs throughout the valve-box and is connected by suitable ports to the supply pipes P leading to the three burners, valves Q for independent regulation of the flow through these pipes being fitted in the box. A port in the channel O also communicates with the pipe M adapted to permit of a continuous circulation of oil through the pump when the burners are cut off, and a valve R is provided for independently cutting off or regulating the flow through the pipe. The burner S being the pilot or station burner, adapted to be constantly alight, and the pipe M are connected to part W of the valve-box, which is always in connection with the oil supply; whilst the burners A, adapted to be cut off on an emergency simultaneously, are connected to the part X. The emergency valve D is arranged so that it can close the main oil channel O and cut off the supply of oil to the part X of the valve-box. A steam supply pipe T is also connected to valve D by the port U, which is also provided with a port V, the ports being arranged in such a manner that when the valve D is partially turned steam is directed therethrough into the part X of the valve-box and so to the burners to blow out any oil remaining therein. A further movement of the valve D cuts off both oil and steam. Independent steam connections are also made through the valve-box to the burner supply pipes and are provided with cocks so that steam may be blown through each burner independently of the others. A thermometer may be provided on the valve box to indicate the temperature of the oil.

In the furnace illustrated in Fig. 3 the burners are fitted in the front plate of the firebox, the burner nozzles projecting inwardly within sleeves extending through the water space included between the front plate of the firebox and the boiler plate, the nozzle being preferably given a slightly downward inclination, as shown. Air is supplied for the combustion of the fuel both through the sleeves and also through air inlets in the outer and inner walls of the firebox, which are controlled by dampers. In the modified construction of furnace shown in Fig. 4 the burners project through sleeves, but extending through the inner or forward wall of the firebox so that the oil and products of combustion are projected rearwardly under the bridge towards the front end of the firebox.

CORES, WITH SPECIAL REFERENCE TO CORES OF SILICA SAND.*

BY F. C. PULSFORD, A.M.INST.M.E.

SOME years ago the company with whom I was engaged experienced considerable difficulty in the removal of core irons from castings of light, hollow form, and it was with some amount of incredulity that my proposal was received to make the cores without irons, rods, or supports of any kind. There did not appear to be any literature on the subject to guide one. Advertisements for foremen with a working knowledge of such method did not yield a satisfactory result, and as my own foreman was somewhat sceptical and unsympathetic, I proceeded alone with my experiments. At that time great pressure of business prevented my giving adequate attention to the subject during the usual working hours, so I proceeded, as will now be described. The first essential was time, which I volunteered out of my evenings; then a few gallons of core compound, which I obtained from the United States of America. It was Syracuse core oil. Whilst the compound was being conveyed across the Atlantic I was hustling around for a sharp sand, cheap and of suitable fineness, and obtained a sack from the Weymouth foreshore.

Well, eventually the supply of liquid core compound was delivered, also the sharp sand, after which the real trouble commenced. The advised quantity of core compound was mixed with water, applied to the sea sand, and after much turning and mixing of the sand to ensure every grain having a rubbing acquaintance with its neighbour, I commenced on the ramming operation, and duly stoved the core, giving it an over night drying. The outcome was most unsatisfactory. It was evident that I had used too much muscle but too little brain, with the result that the core was most obstinately glued to the iron box in which it was dried, and was only removed from it by a fettler's hammer and chisel. I would point out here that the important factor of temperature in the drying stove was an unknown quantity. The core stove was of the ordinary coal-fired variety, and had done service for 25 years. It was of the pudding-bag type—the entrance was also the exit—firing also being done from the same end.

I mixed another quantity of sand, using the Syracuse liquid compound, but I added to the sea sand a proportion of spent sand from the fettling shop: one part of old sand to two parts of new sea sand. The core was also more carefully dried, and not having had so much fire was more satisfactory. I proceeded along these lines until I began to collect a few cores, which were hung around my office as an evidence that something was being done. Hereabout a new trouble appeared. The cores were 36in. long, of oval section, about 3in. by ¾in., and were continued around the end of the box, giving three legs coupled up together at both ends. The cores contracted a little whilst drying, and as it was necessary to give a slight tap to the core box to loosen the core from its walls, fracture invariably occurred. I patched up a few cores with core gum, and by such means succeeded in obtaining a cast. The result was most satisfactory; the core withstood the pressure of casting, and when the casting cooled off a few taps with a wooden mallet removed the core, leaving a bright glossy interior to the casting, which was one of the problems I had to solve.

Experiments with cores of different sections were still more successful. Core pans were made with all sharp edges worked into an easy radius. A little dry, or parting sand, dusted on the face of the core pans solved the difficulty of both contraction and adherence. Such results, however, were not readily attained. Numerous experiments were made with several American liquid compounds, also linseed oil, cottonseed oil, and fish oil, but the most satisfactory result was secured by using the production of the C. E. Mills Company, of United States of America. It was a compound which more nearly resembled linseed oil than any of the others I had used. Patent gums, resin, pea flour, and many other compositions were brought into requisition, but the C. E. Mills oil binder was the only one that gave all-round workable results. Its chief drawback was its high cost. This result and opinion had taken a long time to obtain, for the experiments passed through many vicissitudes, little sympathy and no encouragement, until it seemed to me that failure and not success would be more vigorously welcomed by my colleagues.

At this period personal contact with the managing director resulted in my visiting the United States, where, although I carried numerous letters of introduction, these failed to get me into most of the plants I was anxious to visit, and where I could observe for myself what was being done on similar work. Eventually I did succeed in getting on the sand floor of two plants, and the observations I made were sufficient to indicate I was proceeding on right lines at home. When I returned here I continued on the old lines with the Mills compound until eventually I got hold of a foreman who had had some Yankee experience. He was young and enthusiastic, and so fell in with my ideas, and with his sympathetic assistance the result I had anticipated seemed assured, and eventually became an accomplished fact. With the foreman's co-operation these special cores, without rods or supports of any kind, were further cheapened by the introduction of cold-drawn cod oil as a substitute for the Mills compound, and

* Paper presented at the annual convention of the British Foundrymen's Association, Leicester, May 12th to 14th, 1914.

also by the addition of black floor sand. Beeston Rock sand and Bedford pit sand were also introduced instead of Sutton sea sand, which we were then using, until we were able to produce all our intricate cores without rods or supports, or with the minimum support where experience suggested such was advisable. The outcome of these re-arrangements was very satisfactory, for we were now able to improve the fineness on the interior of the castings, at the same time to decrease the cost of the cores, and also to obtain the oil from our home markets, which was an advantage, as it enabled us to carry less stock. My experiments with these cores lead me to the following as being the best mode of procedure:—

Mixing.—Care must be taken with the mixing. It is preferable to well mix the old floor sand, the Beeston, Bedford, and spent sand thoroughly whilst in a dry state. The mixing is best done by hand. When using a mixer of the centrifugal type the heavier grains of sand separate from the lighter particles at different points and an unequal mixture results, the coarse grains being at the extreme edge of the mixture, as will be well understood. After the sand has been thus thoroughly mixed by hand, the oil should be added. If it is necessary to add water it is best to add it to the oil and well mix until emulsified. After thoroughly turning over the sand and oil mixture a few times it should be passed through a ¼in. mesh riddle.

Ramming.—Don't ram hard. A dolly rammer is all that is necessary unless the box is too small for such a tool. In any case, whatever core is being made, the sand only requires to be tightly tucked home.

Patching and Venting.—Free vents are essential as a lot of gases have to escape when pouring. With oil-sand cores no patching nor external venting is necessary. Coke breeze, hay, &c., and all the ramifications a coremaker needs to secure "a good job" are dispensed with; the time required to iron weak parts, the difficulty of ramming around these, and the cost of irons, may be eliminated from much of the work in the core shop by the adoption of oil-sand cores. The method is, of course, more ideal where repetition work is a speciality, but it can with advantage be adopted for much of the jobbing work passing through our foundries every day. The method requires perseverance to achieve success, also the breaking down of foolish opposition, which usually emanates from the ignorant or prejudiced, or perhaps from the person who is content to do as his father did before him, considering that way good enough. Objections have been raised to the use of oil-sand cores on account of the odour when casting. When pouring off a good deal of gas is generated, but a reasonably ventilated foundry is able to deal successfully with the fumes. No evil effects attend the men who work this process. We have been busy with it for 11 years and the men have no fault to find.

Drying.—Experience has shown that the term drying is not suitable. The process is better termed baking. Care must be exercised at this stage, otherwise a whole oven-full of cores may be scrapped; for after a certain temperature the cohesion of the sand particles diminishes and the cores become useless. We have long since used a recording pyrometer of the Bristol type, and we find if the cores are baked at about 400° Fah. satisfactory results are obtained. These cores will remain good for days after baking, even if removed from the stove, as they do not absorb moisture like the usual loam-sand core.

Core Pans or Shells.—If the job on hand is not repetition work, oil-sand cores may still be used by the judicious adoption of frames which will surround the core. If such a frame is being used, ordinary damp spent floor sand can be packed around the core and well secured by pressure, but this pressure must not be enough to distort the shape of the core, which is very fragile and practically without bond. The cores should be covered with an ordinary carrying plate, turned over and out of the core box just as would be done with ordinary cores. On account of the economy, the facility of production, and the ease with which the fettlers can perform the interior cleaning, I can with confidence recommend the method to the careful consideration of foundrymen.

Green-sand Cores.—During last year I introduced into our foundry the manufacture of green-sand cores for bends, tees, and straight pipes. Our foreman is a real good fellow, but trained in the old school, and about as conservative as you could find. He walked past a new repeat pipe job day after day until the ultimatum was made to him to put the job in work, or I would. He confessed he was afraid. Thousands of tons of metal are, of course, being poured every year in various districts of the country with green-sand cores, but here we are encompassed with prejudice. Needless to say, the introduction proved successful here, and as there is not anything new in it, I claim no achievement I merely mention the fact as an instance of what can be done by perseverance and determination to succeed, but this must be backed by some knowledge of the ironfounder's art, an intelligent conception of its possibilities and the removal of prejudice, by which means only can success be assured.

A LOCOMOTIVE SMOKE PROSECUTION CASE.

A SOMEWHAT unusual "black smoke" prosecution case came before the Salford Stipendiary Magistrate (Mr. W. P. Atkin) on the 27th ult., when the London & North-western Railway Company were summoned under the Salford Improvement Act, 1862, for having permitted dense black smoke to issue from the chimney of a locomotive engine on April 24th. Mr. S. Carnt, deputy town clerk, prosecuted on behalf of the Corporation, and Mr. Branthwaite appeared for the railway company. Inspector Deakin stated that while he stood on the Ordsall Lane station waiting for the train to which the offending engine was attached he saw it approach emitting dense black smoke. While the train stood in the station this continued. He called the attention of the driver, who immediately put a stop to it.

Mr. Branthwaite suggested that the whole period of observation did not cover three-quarters of a minute, but the witness said it would be about two minutes. Mr. Branthwaite said this engine was fitted with proper smoke-preventing appliances which were all in perfectly good order. But, no matter how perfect appliances were, it sometimes happened that a jolt would cause the adjustable firedoor to slip from its bracket and momentarily cause the black smoke to be emitted, as in this case. The engine-driver gave evidence, and said that he reopened the firedoor as soon as possible of his own accord.

Mr. Joseph Beaumont, chief engineer for the L. & N.W. Railway Company at Crewe, said the engine was of the most perfect type for the consumption of its own smoke, but it frequently happened that a firedoor would slip from a bracket without the driver being in any way negligent. Mr. Branthwaite said this was the first instance in which the London and North-western Company had been prosecuted for such an offence, and he urged that it was not sufficient to convict that black smoke should be emitted for two minutes. It must be further proved that all practicable precautions had not been taken, and he submitted that in this case they had.

The Stipendiary Magistrate said he considered the case proved, but as it was the first offence of the railway company he would impose the lowest fine possible under the section—that was 40s. It seemed to him unfair, however, that a railway company should be dealt with more severely than a mill for a slight first offence like this. A millowner would only have been fined 10s., therefore in inflicting a fine of 40s. and costs he would remit 30s. of it.

Seventh Congress of the International Association for Testing Materials. — The seventh congress of the International Association for Testing Materials will be held under the patronage of H.M. the Czar of Russia, in St. Petersburg, from August 12th to 17th, 1915. Four days will be devoted to the discussion of the most important problems on testing materials. After the congress extensive excursions in the interior of Russia have been arranged. The offices of the British Section of the association are at the Iron and Steel Institute, 28, Victoria Street, London, S.W.

THE OCTO WELDING PROCESS.

DURING recent years quite a number of methods have been devised for the welding of metals. One of the most successful of these is that known as the Octo welding process, which has been introduced by Octo Welding, Ltd., 6, Hanway Street Works, Oxford Street, London, W. By means of this process broken parts of machines, &c., which were usually scrapped, can be repaired in an efficient manner, resulting

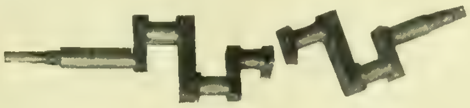


FIG. 1.



FIG. 2.

not only in considerable saving in money, but also in time, as repairs can in many cases be completed in 24 hours, thus avoiding the delays which usually occur in obtaining new parts.

It is desirable to point out that for the efficient welding of metals, which is a highly technical operation, skilled workmen are essential. The average mechanic is not a metal expert and knows little about "fusion point," "mirror" alloy tests, and percentages, and all the other scientific considerations which must be at the finger ends of every welding operator who can claim to a sound knowledge of his subject. Some interesting examples of repairs effected at the works of Octo Welding, Ltd., where only skilled operators are employed, are shown in the accompanying photo views. In the case of the fractured crank shaft shown in Fig. 1, taken from a 16 h.p. car, the shaft was broken in two at one of the centre webs. By means of the Octo process the repair was effected in a perfect manner in less than 24 hours, as indicated in Fig. 2. This work involved not only the actual welding, but also machining and lining up.

The cylinder unit shown in Fig. 3 is another example of perfect welding repair work. In this instance the combustion head was blown completely out and part of the water

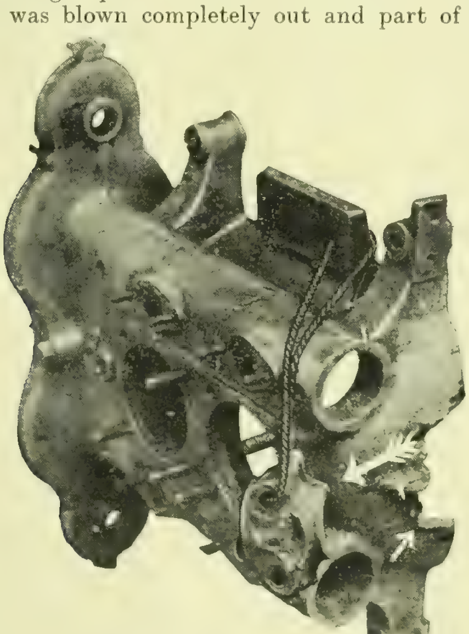


FIG. 3.

jacket carried away. When it is considered to what tremendous stress the combustion head of a cylinder is subjected, the fact that this repaired unit (*see* Fig. 4) has been back at work in its engine for months past, and has given entire satisfaction, indicates the efficiency of Octo welding.

A further interesting repair is that to the crank chamber shown in Fig. 5. It will be seen that the main end bearing was completely broken away, and that the wall of the chamber itself was badly cracked. Fig. 6 shows how the Octo welder finished the work. There is no trace whatever of the weld; the job is as clean and true as though machined to



FIG. 4.

pattern. The repair was effected absolutely without any distortion whatsoever.

In addition to the special departments dealing exclusively with automobile welding repairs, which are equipped to deal effectively with the repair of any car part in any metal or alloy, the firm have other departments for dealing with

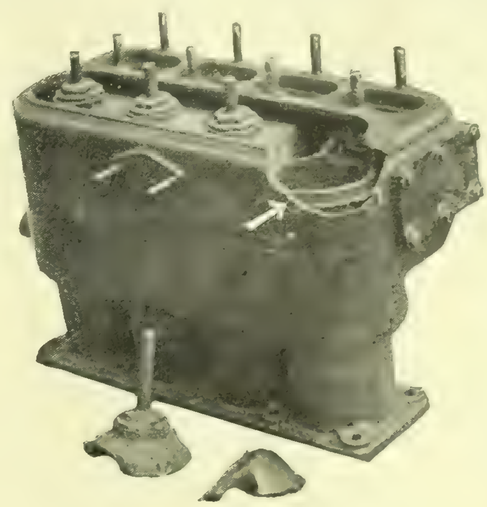


FIG. 5.

heavy machine repairs, and maintain a staff of expert operators who can be dispatched at a moment's notice with the necessary plant to repair flywheels, boilers, furnaces, girders, and all similar constructions, as well as traction engines, ploughs, and all other large agricultural machines. As regards the reliability of the process the firm guarantee per-

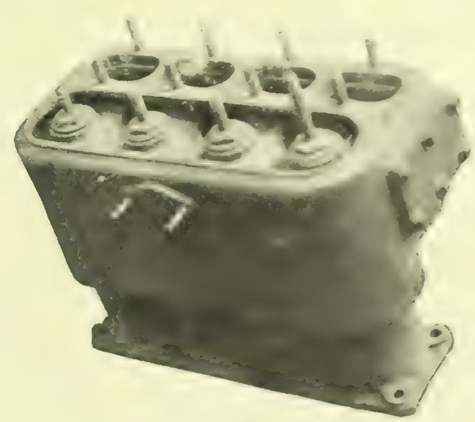


FIG. 6.

fection in every repair undertaken, and even go so far as to offer the refund of all money disbursed by the customer on the repair if the welding shows imperfection in any way.

THE PRODUCTION OF STEEL DIRECT FROM ORE.*

BY ERNEST HUMBERT AND AXEL HETHEY, B.SC.

THE first iron and steel that we know of in history was produced by more or less direct reduction of iron ore, in somewhat primitive furnaces. The best examples of this material are afforded by the old Damascus and Toledo blades. Although the steel of which these swords were made was sometimes of very uneven composition and full of slaggy enclosures, it certainly possessed remarkable qualities of strength, endurance, and toughness. It is, even nowadays, difficult to produce material to equal these old direct steels. Direct iron and steel has been made all over the world, usually in districts where simple surface ores were found with a convenient supply of charcoal. Modern methods of manufacture, however, with their large productions and consequent cheapness of manufacture, have in the last century displaced these direct processes.

Now that modern conditions demand such severe specifications for steel, the steelmaker is daily experiencing greater difficulty in meeting these demands, with the result that he has had to go from a simple carbon-manganese iron alloy to costly and complicated alloys of iron with more or less rarer metals. The difficulty experienced in eliminating such impurities as oxygen, phosphorus, sulphur, and silicon, and the practical failure to eliminate nitrogen and hydrogen, led the authors to search for a method of manufacture with which a purer steel could more readily be obtained. Remembering the old adage that prevention is better than cure, and seeing the satisfactory results that were obtained with the old imperfect methods of production, the authors' attention was drawn to direct processes of manufacture. Considering the experiments which Stassano and others made some years ago, and the practicability of the modern electric furnace, it was decided that an ordinary arc furnace would sufficiently fulfil the necessary conditions to enable experiments on a somewhat more practical scale to be made. The ease with which an electric furnace can be controlled, and oxidising and reducing conditions obtained at will, were the chief factors influencing this decision. The various heats were made in a normal Héroult electric furnace of 6-ton capacity and working with single-phase current.

Three series of tests were made:—

Series A.—Direct reduction of siliceous Swedish iron ore. (1) One heat of hard steel. (2) One heat of rail steel. (3) One heat of soft steel.

Series B.—Direct reduction of Swedish and a siliceous Swedish iron ore, with 30 per cent. of scrap mixed with the charge.

Series C.—Direct reduction of Brazilian iron ore.

The materials used and their composition were as follows:

Magnetite Ore from Sweden (Rodberg)

	Per cent.
FeO	0·54
Fe_3O_4	86.02
SiO_2	8·89
CaO	1·02
MgO	1·12
MnO	0·09
P_2O_5	0·023
S	0·015
Cu	traces

Brazilian Ore. Average Analysis (Progneus).

	Per cent.	
Fe	65·00	
Mn	0·10	
Al_2O_3	traces	
MgO	traces	
CaO	0·06	
SiO_2 grey ore	1·22	0·15 to 1·23 per cent.
red ore	2·16	
pisolitic	0·30	
S	0·019	
P	0·039	

Metallurgical Coke.

	Per cent.
C	90·16
Ash	7·33
Volatile matter	2·51

Lime.

	Per cent.
CaO	90·0
SiO_2	1·5

SERIES A.

1. *Heat No.* 866.—The charge was made up as follows:—

	Kilogrammes.
Iron ore (Swedish)	1,000
Coke	200
Lime	100

Six charges of this mixture were prepared, and two were charged on the bottom of the furnace. 30 kgs. of coke in pieces as large as a man's fist were added to start the current. The current was put on at 5-40 a.m. on April 4; at 7 a.m. the load was well established with 8,000 amperes and 90 volts, cos ϕ being $-0·90$. During the first part of the melt violent boiling occurred, and a considerable amount of slag was thrown out of doors. The 30 kgs. of coke, which were added to start the current, were withdrawn at 8 a.m. The slag being acid, 300 kgs. of lime were now added. At 7 p.m. the charge was reduced, and a sample of the metal taken gave carbon $=1·50$ per cent. 1,000 kgs. of slag containing only traces of iron were then removed, and 300 kgs. of iron ore were added in small quantities. At 9 p.m. 50 kgs. of lime were added. At 9-30 p.m. a sample was taken which forged very well and gave 1·20 per cent. of carbon. The heat lasted 16 hours and was teemed at 9-40 p.m. There was an excess of coke on the slag at the time of pouring.

Total Weight of the Charge.

	Kilogrammes.
Iron ore	6,300
Coke	1,200
Lime	950

Weight of Steel Produced.

	Kilogrammes.
Ingots	3,600
Scrap	120

Iron lost in melting, 6·5 per cent.

Electric Energy Used.

Kilovolt ampere minutes	600,962
Kilowatt-minutes	540,866
Kilowatt-hours	9,014
Kilowatt hours per ton of steel	2,397
Corrected for 3 per cent. zero error	2,459

Final Analysis of Steel.

	Per cent.
Carbon	1·39
Phosphorus	0·055
Sulphur	0·038
Silicon	0·13
Manganese	0·26

Forge Tests.—The steel forged well.

2. *Heat No.* 867.—The mixture was made up as follows:

	Kilogrammes.
Iron ore (Swedish)	1,000
Coke	200
Lime	150

Five charges of this mixture were prepared and 1¼ charged on the bottom of the furnace with 200 kgs. of scrap to start the current. The current was put on at 11 p.m. on April 4th. At 11-30 p.m. the load was well established. Boiling occurred during reduction, and slag was thrown out of the doors. Some small pieces of electrodes broke off and fell into the charge. The slag being acid, 200 kgs. of lime were added. At 8-30 a.m. the bath was covered with an excess of coke and the current stopped, and 33 kgs. of coke removed. At 11 a.m. the charge was nearly completely molten and a sample gave 1·50 per cent. carbon. Part of the slag was removed. From 11-10 a.m. to 2-30 p.m. 550 kgs. of iron ore and 200 kgs. of limestone were added, and these produced violent ebullition. Considerable difficulty was experienced in lowering the carbon content owing to the broken electrodes. At 2-40 p.m. the current was stopped for ten minutes, and 200 kgs. of iron ore and 160 kgs. of limestone were charged. At 3-30 p.m. a sample was taken showing 0·45 per cent. carbon. The reaction between the iron oxide and carbon was not completed. At 4 p.m. 60 kgs. of lime and 30 kgs. of coke dust were added, but it was found difficult to obtain a white slag. The following additions were then made:—

	Kilogrammes.
80 per cent. ferro-manganese	12
40 per cent. ferro-silicon	20

The heat was tapped at 5-35 p.m. on April 5th. The time of charge was 18 hours 35 minutes. The length of this heat was due to broken electrodes, which necessitated the addition of a considerable quantity of iron ore.

* Paper read before the Iron and Steel Institute, May, 1914.

Total Weight of the Charge.

	Kilogrammes.
Iron ore	5,850
Scrap	200
Coke	1,000
Lime	1,010
Limestone	260
80 per cent. ferro manganese	12
40 per cent. ferro-silicon	20

Weight of Steel Produced.

	Kilogrammes.
Ingots	3,630
Scrap	85

Iron lost in melting, 4·16 per cent.

Electric Energy Used.

Kilovolt ampere minutes	688,230
Kilowatt minutes	619,407
Kilowatt-hours	10,323
Kilowatt-hours per ton of steel	2,779
Corrected for 3 per cent. zero error	2,862

Final Analysis of Steel.

	Per cent.
Carbon	0·56
Phosphorus	0·023
Sulphur	0·027
Silicon	0·15
Manganese	0·28

Forge Test.—The steel forged very well at all temperatures, and was found to be very tough.

3. *Heat No.* 869.—The mixture was made up as follows:

	Kilogrammes.
Iron ore (Swedish)	1,000
Coke	180
Lime	175

Five charges of this mixture were prepared, and 1½ charges were charged on the bottom of the furnace with 200 kgs. of scrap to start the current. The current was started at 4-30 a.m. on April 6th, and a load was established immediately without any difficulty. The ebullition was less than in the previous charges, and at 5 p.m. practically the whole charge was reduced. A test gave 1·20 per cent. carbon and forged very well. From 5 to 9-30 p.m. 650 kgs. of ore and 100 kgs. of lime were added; an electrode then broke several times and the pieces had to be removed from the furnace. At 10 p.m. a test gave carbon 0·10 per cent., and the steel was found to be over-oxidised. To deoxidise the slag 60 kgs. of lime were added, and, when melted, 30 kgs. of coke dust. Considerable difficulty was experienced in obtaining a white slag. At 11 p.m. the following additions were made:—

	Kilogrammes.
80 per cent. ferro manganese	25
10 per cent. ferro silicon	50

The heat was poured at 11-15 p.m. and took 18 hours and 45 minutes.

Total Weight of the Charge.

	Kilogrammes.
Iron ore	5,650
Scrap	200
Coke	930
Lime	1,035
80 per cent. ferro-manganese	25
10 per cent. ferro-silicon	50

Weight of Steel Produced.

	Kilogrammes.
Ingots	3,580
Scrap	10

Iron lost in melting, 4·66 per cent.

Electric Energy Used.

Kilovolt ampere minutes	661,999
Kilowatt-minutes	595,799
Kilowatt-hours	9,930
Kilowatt-hours per ton of steel	2,760
Corrected for 3 per cent. zero error	2,843

Analysis.

	Per cent.
Carbon	0·23
Phosphorus	0·015
Sulphur	0·030
Silicon	0·11
Manganese	0·47

The increase in carbon was due to pieces of coke from the slag mixing with the metal while pouring into the ladle. The delays were caused by the breaking of the electrodes.

Forge Test.—The steel forged very well and the test-piece bent 180° without a sign of fracture. A ⅜in. round bar of the steel was twisted into a double knot while cold

SERIES B.

Heat No. 870. The charge was made up as follows

	Kilogrammes
Iron ore (Swedish)	1,000
Scrap	1,200
Coke	720
Lime	800

The iron ore and scrap were charged together. The furnace was started at 1 p.m. on April 7th. The charge conducted the current perfectly from the start, and very slight ebullition occurred during the melting. At 11-55 p.m. the furnace was stopped for 15 minutes to pull some scrap which was stuck on the banks down into the bath; 100 kgs. of ore were then added. At 12-30 a.m. a test gave 1 per cent. of carbon, and between 1-30 to 2 a.m. 200 kgs. of iron were taken and added in small quantities. At 2-20 a.m. the slag was drawn off, and 150 kgs. of lime were added, and, when this was fluid, 30 kgs. of coke and coke dust were fed on to the slag. A test gave 0·80 per cent. of carbon. At 2-50 a.m. the following additions were made:—

	Kilogrammes.
80 per cent. ferro manganese	7·5
40 per cent. ferro-silicon	11·0

The heat was poured at 3-15 p.m. and took 14 hours and 15 minutes.

Total Weight of the Charge.

	Kilogrammes.
Iron ore	1,300
Scrap	1,200
Coke	750
Lime	950
80 per cent. ferro manganese	7·5
Ferro-silicon	11·0

Weight of Steel Produced.

	Kilogrammes.
Ingots	2,970
Scrap	215

Iron lost in melting, 18 per cent.

Electric Energy Used.

Kilovolt ampere minutes	536,347
Kilowatt-minutes	482,712
Kilowatt hours	8,045
Kilowatt-hours per ton of steel	2,526
Corrected for 3 per cent. zero error	2,602

Analysis.

	Per cent
Carbon	0·89
Phosphorus	0·014
Sulphur	0·037
Silicon	0.10
Manganese	0·27

Forge Test.—The steel forged similar to tool steel and crucible steel.

SERIES C.

Heat No. 871.—The charge was made up as follows:—

Two Charges.	Kilogrammes	*Three Charges.*	Kilogrammes
Brazilian iron ore	1,000	Brazilian iron ore	1,000
Coke	200	Coke	180
Lime	50	Lime	50

One and a half charges were put on the bottom of the furnace, and 200 kgs. of scrap charged on top to start the current. The furnace was started at 3-50 p.m. on April 7th. The charge conducted well and was quickly melted without any ebullition at 9 p.m. A test was taken which gave carbon 0·05 per cent. At 1 a.m. the metal froze on the bottom of the furnace, being pure iron. The two electrodes were raised and 60 kgs. of coke added under the electrodes. At 2 a.m. a violent reaction occurred, and the current was stopped and 30 kgs. of lime were added. At 8 a.m. a test gave 0·30 per cent. carbon, and the slag was brown. Two-thirds of the

charge were melted and reduced. At 4 a.m. a test gave 0·30 per cent. carbon and the slag was brown. At 4-10 a.m. 10 kgs. of coke dust were added to make a white slag. At 4-30 a.m. the slag was removed. At 5 a.m. 100 kgs. of ore were added to reduce the carbon. At 5-20 a.m. a test gave 0·50 per cent. carbon and the metal was much oxidised. From 5-25 a.m. to 5-45 a.m. the furnace was stopped to pull down a part of the charge, which was stuck on the banks, and which had been reduced to iron. At 5-50 a.m. 10 kgs. of coke dust and 20 kgs. of fluor-spar were added, and at 6 o'clock 20 kgs. of 10 per cent. ferro-silicon and 17·5 kgs. of 80 per cent. ferro-manganese. At 6-30 a.m. the heat was tapped, the metal being very hot. The duration of the heat was 14 hours and 40 minutes.

Total Weight of the Charge.

	Kilogrammes.
Iron ore	5,000
Scrap	200
Coke	1,050
Lime	250
Fluor-spar	20
80 per cent. ferro-manganese	17·5
10 per cent. ferro-silicon	20

Weight of Steel Produced.

	Kilogrammes.
Ingots	3,268
Scrap	90

Iron lost in melting, 2·54 per cent.

Electric Energy Used.

Kilovolt ampere-minutes	618,831
Kilowatt-minutes	556,948
Kilowatt-hours	9,289
Kilowatt-hours per ton of steel	2,709

Analysis.

	Per cent.
Carbon	0·27
Phosphorus	0·031
Sulphur	0·058
Silicon	0.05
Manganese	0·31

Forge Test.—The steel forged very well and welded with ease.

With this heat the authors attempted to prove that steel direct can be made without the carbon being above 0·4 per cent. at any time during the heat. Tests were taken at short intervals to show that the carbon content remained below this figure. Working in this manner, however, more time is taken, as the melting point of a low-carbon steel is much higher and the material is not so fluid. A good carbon content for normal working was found to be about 0·6 per cent.

Consumption of Electrodes.—The electrodes were weighed before they were put into the furnace and after their removal. Two qualities of electrodes were used. For heats 866 and 867 two electrodes made by the normal process were used. For heat 869 one anthracite electrode of the authors' mixture and process was used. During heat 870 a second electrode made by the same process was added. After heat 871 these two electrodes were weighed. The first two electrodes broke several times and their consumption was 36½ kgs. per ton of steel. The two others, made by the latter process, did not break, and their consumption was 32 kgs. per ton of steel.

Wear of Furnace Lining.—The wear was approximately the same as when melting scrap. For the first heat the roof was attacked by the violent ebullition. With a furnace especially constructed for this class of work this will be avoided, and these repairs would be very small.

Theoretical Considerations.—The charges are divided up into portions so as to make melting easier. It is important to have the various constituent materials of small and equal size (nut size). Coke or scrap is added in each case to establish the electrical circuit readily. Melting proceeds quite normally. Reduction of the ore also follows normal chemical laws. There is much ebullition owing to the large volume of oxides of carbon set free from the liquid bath. This is an essential difference from the reactions in modern blastfurnaces, where spongy iron is first produced and then melted. When all the ore is reduced, the slag should be taken off the bath, and the charge treated as an ordinary pig and scrap charge. If the bath contains too much carbon, ore should be added; if too little carbon, the charge should be recarburised in any convenient manner. A final basic slag, consisting of lime and treated with coke to produce a slag containing calcium carbide, should be obtained to reduce any excess of oxide. The final additions of ferro-manganese, ferro-silicon, &c., are added and the heat finished and poured in a normal manner. Care should be taken that the slag is kept fluid and basic during reduction. A minimum of 0·5 per cent. carbon should be retained during reduction, as the iron may otherwise freeze on the bottom and cause delay and trouble. If scrap be used in the heat, it is better first to reduce the ore with an increased excess of carbon and to add the scrap when this charge is melted and ebullition dies down. The scrap should not be added with the ore. The charge will then melt more quickly and a quieter melt be obtained.

The outstanding quality of steel produced by this process is its toughness. From the rough forge tests made at the furnace it was found that the steel would readily bend without fracture even when containing high percentages of carbon. In one case a drill made from heat No. 870 and subjected to an unusual strain was bent 25° from the horizontal. The authors regret very much that they were at the time unable to make any close analyses and other investigations of the material, but hope to present the results of a closer study of the subject in a future communication. To one point, however, they would like to draw attention.

More and more is now being heard about the presence of gases in steel and their baneful influences. This applies more especially to the presence of nitrogen and hydrogen in steel, and it must be reckoned a distinct advantage of this process that these gases are never introduced into the charge. The only gases that can be imagined as present are oxides of carbon with possibly traces of hydrogen. The effect of nitrogen on steel is generally considered to cause an increase in tenacity and hardness, thus producing brittleness and a decrease in elongation. It is usually considered that nitrogen has about five times the influence which phosphorus produces in that direction. It might be appropriate here to call attention to the importance of considering the quantity of nitrogen in steel. Opinions are much divided on that point, to a great extent owing to the absence of ready and reliable methods of analyses. A rough rule to ensure safety in specifications has been suggested as follows: The percentage of phosphorus plus five times the percentage of nitrogen should not exceed 0·06 per cent. The following figures show the quantities of nitrogen present in steels of different carbon content:—

1·15 per cent. carbon contain 0·030 to 0·035 per cent. nitrogen.
0·5 ,, ,, ,, 0·040 to 0·045 ,, ,,
0·2 ,, ,, ,, 0·050 to 0·060 ,, ,,

These amounts of nitrogen may be taken as critical limits at which elongation begins to disappear, and the steel is found to be very brittle. The presence of nitrogen is perhaps the cause of much of the brittleness found in many hard steels. The limits depend on the carbon content, and it will be noted that hard steels are rendered more readily brittle than mild steels. Nitrogen is supposed to be present in the ferrite constituent of the steel as a nitride. It does not combine with the iron carbides. Nitrogen is added to steel by means of the air-blast in the case of blastfurnaces, converters, and cupolas. In the case of open-hearth furnaces, it is probably added in the shape of cyanogen and ammonium compounds by means of the flame.

To produce high carbon steels of highest qualities in the open-hearth furnaces, the gases should therefore be purified. Crucible steels are found to contain very little nitrogen. Commercial steels usually contain between 0·03 to 0·04 per cent. The most satisfactory substance for removing nitrogen from steel appears to be vanadium, which is, however, expensive to use.

The effect of hydrogen on steel is also little understood, but its action is probably similar to that of nitrogen. This may be inferred from the following example: When steel is pickled, nascent hydrogen is absorbed and the material is more brittle. Annealing, however, overcomes this effect by

eliminating the absorbed hydrogen, and brings the material back to its original ductile state.

Although the authors have been unable to make analyses of the gases contained in this material, they conclude that from the nature of the process and the toughness and ductility of the material obtained, both nitrogen and hydrogen are either absent or present in infinitesimal quantities. The question is one that commends itself for investigation.

Conclusions. — The authors have come to the conclusion that with the aid of the modern electric furnace, and given satisfactory conditions, the economic manufacture of steel direct from ore is a practical possibility. The material produced will be superior to that manufactured by present methods, and will have properties of the greatest importance and value to the steel user. A special type of furnace will probably be developed, although the standard Héroult furnace is satisfactory for occasional charges. The charge should lie deep in the furnace, to permit violent ebullition of the bath without overflowing. Anthracite electrodes will probably be found most satisfactory owing to their freedom from breakages. The best use for this process will be found in countries that possess readily available sources of water power together with deposits of pure, rich ores. Charcoal, coke, or anthracite coal can be used as fuel. In countries where cheap power, produced from waste heat such as blastfurnace gases, coke-oven gases, &c., can be obtained, its most useful sphere will probably be found in making high-grade steels for springs, drills, and similar tools, shafts, and all grades requiring exceptional toughness.

Economic Advantages of this Process.—(1) One operation instead of several. (2) One furnace instead of a large and complicated plant. (3) Simplicity, cleanliness, and ease of control of electricity as a source of fuel and power. (4) Ability to use refractory and richer ores, such as titaniferous magnetites, &c. (5) Freedom of the steel from impurities. (6) Speed of manufacture. (7) General cost depends largely on cost of electric power, but will be cheaper than the electrical production of steel from pig iron. (8) Less labour needed. (9) Metallurgical simplicity of the process. (10) Efficient control of quality of steel to be obtained, both from an analytical and physical point of view.

INDUSTRIAL AND TRADE NOTES.

Personal.—The Home Secretary has appointed Mr. W. Walker His Majesty's Inspector of Mines in charge of the Scotland Division, to the newly-created post of Deputy Chief Inspector of Mines at the Home Office.

Union of Shipbuilding Firms.—An arrangement has, we learn, been concluded, whereby an exchange of shares is effected and a community of interests ensured between the two shipbuilding firms of Messrs. Swan, Hunter, & Wigham Richardson, of Wallsend and Walker on Tyne, and Messrs. H. & C. Grayson, of Liverpool and Birkenhead.

New Clyde-built Destroyer.—The torpedo-boat destroyer "Miranda," built by Messrs. Yarrow & Co., Glasgow, for the British Admiralty, was launched on the 27th ult. This vessel, one of the three special destroyers ordered from Messrs. Yarrow and Co., is of their own design. She is 260ft. long by 25ft. 7in. beam. The contract speed is 35 knots. She is fitted with Messrs. Yarrow's latest type of water tube boilers and superheaters.

Hours and Output in Shipyards.—At the adjourned conference in London on the 26th ult. between the Engineering Employers' Federation and representatives of the Federation of Engineering and Shipbuilding Trades, on the demand of the men for a 48 hour working week, the Federation representatives intimated that they were unable to give the guarantee the employers demanded, that the output per week would not be reduced, but they believed that by better timekeeping and other economies the reduction would be kept at a minimum. The matter is to be referred to the Employers' Federation.

North of England Ironworkers' Wages.—The return made to the North of England Iron Trade Conciliation Board shows that the production of manufactured iron in March and April was 9,077 tons, an increase of 283 tons on the previous return, but a decrease of 3,932 tons compared with the same period last year. The net average selling price of bars was £6. 16s. 6d., plates £6. 7s. 0·46d., rails £6. 6s. 7d., and angles £7. 2s. 11d. Under the sliding scale there will be a reduction of 3d. per ton on puddling and 2½ per cent. on all other mill and forge wages.

Three Months' Railway Accidents.—During the three months ended December 31st, 1913, the total number of casualties on the railways of the United Kingdom in the course of public traffic was: Killed 305, injured 2,399, compared with 278 and 2,356 respectively in the corresponding period of 1912. Of these 9 passengers were killed and 197 injured from accidents to trains, rolling-stock, &c.; while 31 were killed and 575 injured by other accidents. Of railway servants, &c., 109 were killed and 1,540 injured by accidents in both these categories, while 19 persons were killed and 10 injured at level crossings. Of trespassers, including suicides, 127 were killed and 30 injured. Ten persons on business at stations, &c., were killed and 47 injured. In addition, 14 persons were killed and 6,433 injured by accidents in which the movements of railway vehicles were not exclusively concerned.

State Purchase of Railways.—The text of the Nationalisation of Railways Bill has just been issued. The Bill gives power to the State to purchase the railways either as a whole or in instalments and hand them over to a Minister of Posts and Railways, who will also take over the Post Office. The purchase price will be paid in State railway stock, which is to be redeemed within 63 years through a sinking fund. A railway board is to be formed to operate the State system under the Minister for Posts and Railways, and there is to be a railway council representative of local authorities, industry, agriculture, and commerce, which will advise on questions of rates, fares, and wages. Its decisions will be binding on the board of management if they are approved by the Minister. The members of the Board are to be paid (as the present railway directors are), but must give their whole time to their duties. The members of the Railway Council are to be unpaid, but to have free passes over the State system.

British Trade with Brazil.—In his report for the past year on the trade of the Consular district of Porto Alegre, Dr. T. Cantrell Dillon, the British Consul, says the greater part of the importation from Europe is from the United Kingdom and Germany, in about equal shares. Much of the machinery imported is of German make. Agricultural implements and machinery (which are duty free) come principally from the United States. Enamelled goods come chiefly from Germany, as do cheap ironmongery and tools; the better kinds of these goods are of British manufacture. Welded iron tubes, galvanised iron roofing sheets, tinplates, and hollow-ware come almost exclusively from the United Kingdom. Fencing wire formerly came principally from Belgium and Germany, but is now imported on a large scale from the United States, which country is making vast and rapid strides in trade in this country. Iron sheets, rods, bars, hoop iron, and other similar products come chiefly from Germany. Pig iron is imported almost exclusively from the United Kingdom, as are copper bottoms and sheets. Rails for tramways come from Germany, for railways they come from Belgium.

Shipbuilding at Antwerp.—Sir Cecil Hertslet, the British Consul-General at Antwerp, in his report for the past year, points out that all the building yards at that port were fully occupied and a record tonnage was turned out, amounting to 30,137 tons gross. The total tonnage launched during 1913 shows an increase of 11,350 tons over that of 1912. The prospects for 1914 are good in the Belgian building yards. It is curious, he adds, that at the time the British press referred to an order passed to shipbuilders at Dunkirk for British vessels no mention was made of the fact that a number of steamships have been constructed at Antwerp for British owners. In 1912 two vessels of over 1,200 tons each were launched at Antwerp for the British flag. During 1913 three steamships, measuring respectively 1,276, 1,950, and 4,026 tons gross, were launched at Antwerp for British owners. Since the year (1913) to which these figures refer—viz., in February, 1914—a large British vessel, the "Lowther Castle," of 4,333 tons gross, has been launched from the yards of the Antwerp Engineering Company at Hoboken, and is the largest British vessel that has ever been built in Belgium. The fact is noteworthy as showing the progress which is being made in ship construction at Antwerp.

The British Acetylene and Welding Association.—The thirteenth annual general meeting of the association was recently held in London. Mr. E. W. Sprott read a report of the work done during the year, and also mentioned that the membership had greatly increased. Mr. T. G. Allen was elected president for the present year, Mr. C. E. Bingham vice-president, and Mr. C. George was re-elected treasurer. Two papers were read, one on "The Welding Schools," by Mr. K. S. Murray, and "The Testing of Carbide," by Mr. C. E. Bingham. Particulars as to the welding schools can be obtained from the association at 103-104, Cheapside, London.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1912.

Carburetters of internal-combustion engines. Redknap. 26299.

1913.

Starting systems for engines. Kettering. 3655.
Feeding devices for oil engines. Renault. 6357.
Vaporisation of liquid fuels for internal combustion engines. Tivey & Dale. 10726.
Scale scrapers for boiler tubes. Nirascou. 10784
Heating installations. Mellersh-Jackson. 10799.
Internal combustion motors. Miller. 11027.
Transmission of power by chains and pulleys. Jeffreys & Muirhead. 11151.
Rotary valves for internal-combustion engines. Ellis. 11291.
Laminated springs. Bradburn, Forder, & Forder. 11319.
Automatic coupling gear for railway cars. Garankin. 11337.
Bedplates or frames of internal combustion engines. Bentall and Bingham. 11344.
Steel manufacture. British Thomson Houston Company. 11370.
Muffle and similar furnaces. August's Muffle Furnaces, Ltd., and August. 11386.
Cooling and lubricating the valves of internal combustion engines. Herr. 11479.
Instruments for measuring the velocity of flow of fluids. Contzen. 11513.
Wire ropeways. Conrad. 11730.
Vaporisers or carburetters for internal combustion engines. Myers. 11763.
Carburetters for internal-combustion engines. Myers. 11764.
Carburetters. Myers. 11765.
Engine starters. Myers. 11766.
Valve gear for internal-combustion engines. Jones. 12541.
Internal combustion engines. Atwood. 12733.
Means for automatically controlling and regulating winding engines. Butterley Company, and Drabble. 12764.
Force feed lubricators. Electric Ignition Company, (1913), and Harper. 13211.
Speed controllers. Douglas. 13887.
Apparatus for stopping trains independently of drivers. Brunskill. 14906.
Four stroke cycle explosion motors. Soc. des Moteurs Gnome. 14975.
Valves. Skelland. 15451.
Safety suspending devices for mine cages. Pearson. 18214.
Steam traps for low pressure steam-heating systems. Bousfield. 18825.
Furnace efficiency meters. Blonck. 19558.
Chain grate furnaces. Bennis. 20079.
Power transmission mechanism. Phillips. 20298.
Self starters for internal-combustion motors. Diehl. 20823.
Reversing gearing for cranes. Babcock and Willcox, Ltd., and Hollick. 22141.
Explosion-engine valves. Pfleiderer. 23870.
Explosion motor having cylindrical slide valves. Vernaz & Pictet. 24225.
Carburetters for oil engines. Snapper. 26118.
Two stroke internal combustion engines. Every Clayton. 28115.
Automatic air inlet controlling device for internal combustion engines. Langan. 28416.
Sand moulding machines. Oetling. 28526.
Fire bars. Bennis. 29103.

1914.

Internal-combustion engines. Anzani. 387.
Cooling of cylinder covers of internal-combustion engines. Maschinenfabrik Augsburg Nurnberg Akt Ges. 965.
Ball bearings. Deutsche Waffen und Munitionsfabriken und Heinrich. 2295.
Adjustable spanners. Muller. 7307.
Valve gear for internal-combustion engines. Bentall & Bingham. 8667.

ELECTRICAL, 1913.

Electrical printing telegraphs. Soldatencow 3326.
Trolleys for electric traction systems. Munro, and R.E.T. Construction Company. 3857.
Systems for supplying from high pressure mains continuous current at a lower pressure. Graham & Rickets. 10920.
Means for controlling electric circuits. Leitner. 11115.
Telephone exchange system. Corwin. 11177.
Wireless telegraph transmitters. Marconi. 11371.
Means for detecting continuous electrical oscillations. Marconi's Wireless Telegraph Company, and Franklin. 11453.
Synchronous dynamos. Rosenberg. 11506.
Trolleys for electric traction systems. Munro, and R. E. T Construction Company. 11629.
Production of electrical resistance materials. Resisto-Electrical Manufacturing Company, and Ruzicka. 11975.
Electric arc lamps. Railing & Angold. 12,919.
Devices for braking electric motors. Klinkenberg. 13135
Electric elements for cooking. Venner. 13988.
Sparking plugs for internal combustion engines. Electric Ignition Company, (1913), and Cox. 15974.
Manufacture of electrolytic iron. Soc. Anon. "Le Fer." 16565.
Electrodes for searchlights. Geb. Siemens & Co. 28286.
Current interrupting devices for electric igniting apparatus. Schröter & Küster. 28535.
Electrolytic converter for the transformation of alternating current at a lower pressure. Graham & Rickets. 10920.

1914.

Electrical control systems for motors. Girardelli. 1265.
Arc lamps. Hughes. 2737.

METAL QUOTATIONS.

TUESDAY, JUNE 2ND.

Aluminium ingot	86/- per cwt.
,, wire, according to sizes, &c. ......from	107/4 ,,
,, sheets ,, ,, ... ,,	112/- ,,
Antimony	£27/-/- to £28/-/- per ton.
Brass, rolled	7¾d. per lb.
,, tubes (brazed)	9⅜d. ,,
,, ,, (solid drawn)	7⅞d. ,,
,, ,, wire	7¼d. ,,
Copper, Standard	£63/-/- per ton.
Iron, Cleveland	51/3 ,,
,, Scotch	57/3 ,,
Lead, English	£19/10/- ,,
,, Foreign (soft)	£19/2/6 ,,
Mica (in original cases), small	6d. to 3/- per lb.
,, ,, ,, medium	3/6 to 6/- ,,
,, ,, ,, large	7/6 to 11/- ,,
Quicksilver	£7/-/- per bottle.
Silver	26⅛d. per oz.
Spelter	£21/7/6 per ton.
Tin, block	£142/15/- per ton.
Tin plates, I.C.	12/3 per box.
Zinc sheets (Silesian)	£24/10/- per ton.
,, (Stettin; Vieille Montagne)	£24/12/6 ,,

Institution of Water Engineers. —The summer meeting of this Institution will be held at Stockport on the 11th, 12th, and 13th of June. Several important papers will be read and discussed during the meeting, while an interesting programme of visits to works has been arranged. The president of the institution is Mr. Thomas Molyneux, waterworks engineer to the Stockport Corporation.

The Junior Institution of Engineers: North-western Section.—A meeting of this section was recently held in Manchester, when a discussion on "The Use and Abuse of Gauges" was opened by Mr. J. Hulme. Various types of gauges were explained and, in many cases, illustrated by samples, which included callipers, micrometers, Vernier limit gauges (both snag and ring and plug), and length rods. The value and necessity of gauges in multiple manufacture was expatiated upon and practical results detailed. The question of interchangeability of parts, especially of replacements at long distances from the manufacturers' works, was dealt with, it being pointed out that wear of existing parts may easily prevent a new part (although absolutely to gauge) giving satisfaction when introduced into an old machine. Numerous instances were given of the abuse of gauges, such as physical abuse of the gauges themselves, using a gauge on a part that was afterwards painted, using gauges whose limits had been improperly determined, and failing to instal an inspection department along with the introduction of gauges into a factory.

The Mechanical Engineer.
An Illustrated Weekly Journal
Vol. 33, No. 855.

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Telegrams: "Scientific," Manchester.
Telephone No. 6055 City.

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Measurement of Smoke Density from Boiler Chimneys.

The last issue of "The Electrician" gives a description of an interesting piece of electrical apparatus that has been devised by Prof. W. W. Strong, an American investigator, who has for some time been devoting himself to various questions relating to the smoke problem. As many steam users and engineers who have had to deal with smoke prosecutions here will be aware, the question of smoke density is a point on which the evidence is often contradictory. "Black smoke," as it issues from the chimney top is, in the absence of scientific standards of comparison or measurement, not easy to define, and it is difficult to controvert the evidence of a smoke inspector who tenders nothing in evidence but his unchecked statement when a prosecution is instituted. Though magistrates have usually little but this to go upon in judging offences, it cannot be considered satisfactory, and in view of the Departmental Committee now sitting and the importance which promises to attach before long to the whole problem of smoke emission in manufacturing towns, reference to the methods of measuring smoke density may be opportune. Several have been devised, the best known and probably the most practical so far being that introduced by Ringelmann, who adopts six conventional scales ranging from white to black, with four intervening shades, Nos. 1, 2, 3, and 4. No. 1 is formed by ruling black parallel lines 1 mm. thick at right angles to each other 10 mm. apart from centre to centre so as to form white spaces 9 mm. square; in No. 2 the lines are 2·3 mm. thick and 7·7 mm. apart; in No. 3, 3·7 mm. thick and 6·3 mm. apart; and in No. 4, 5·5 mm. thick and 4·5 mm. apart. These four scales practically constitute the standards of comparison, since the extremes of all white or all black seldom come into consideration. Sheets of paper about 18in. square with scales ruled as indicated, when placed at a distance of

about 60ft. to 80ft. (depending on the eye of the observer), resolve themselves into a uniform tint which, if placed between the observer and the chimney, may be used for the purpose of comparison with smoke issuing from the chimney, and, if there be two observers to confirm these comparisons, they obviously may be regarded as fairly reliable. The method, it must be admitted, is somewhat clumsy, and, owing to the position of buildings, &c., is not always applicable, but when it is it at all events affords more rational comparisons than the individual judgments of observers, resting only on memory and affected by the condition of the sky, as well as their position with regard to the smoke and whether it is seen by reflected or transmitted light. Observers themselves differ as to what constitutes "light," "dark," and "black," and the most unprejudiced one watching a stream of smoke of changing density will find great difficulty in drawing dividing lines. The defects in Ringelmann's methods were largely rectified in an instrument shown by the Austrian Society of Steam Boiler Owners at the Paris Exhibition in 1900. This instrument consists of two concentric tubes, the inner one having glass ends and being also fitted with branches so that a continuous stream of smoke or furnace gas can be led continuously through it. One end of the inner tube is illuminated by an electric lamp of definite candle-power. At the opposite end is a transparent annulus with Ringelmann's scales to a reduced pattern drawn upon it, so that the scale and colour of the smoke as seen through the inner tube are viewed from the same source of light and thus permit of comparisons being made between the scales and the smoke in the internal tube. Though instruments of this kind have been used on the Continent, they have not so far as we are aware been adopted in this country, and it would not be difficult even to raise objections to smoke density readings taken in this way owing to troubles in securing fair samples of smoke, and the fact that the instrument does not furnish a record. The new type of electrical indicator devised by Prof. Strong aims to remedy some of these defects, but as it involves considerable electrical knowledge to understand its working and operation it will hardly appeal to the average steam user or engineer in charge. Briefly, the action of the apparatus turns upon the fact that flue gases when smoke is not present are strongly ionised, in other words, are a better conductor of electricity, so that if an alternating current is applied to a spark gap placed in the flue and so adjusted that a discharge takes place when the flue gases are normal, the presence of additional smoke will prevent electrical discharge and cause in that event the discharge to pass between two other spark gaps situated outside the chimney under ordinary atmospheric conditions, in which case, by means of suitable electrical connections, it may be made to ring a bell or control some other signalling device within sight of the stoker, who is often so situated that he cannot see the chimney top and thus make him aware that the smoke conditions are abnormal. Such, briefly, is the theory of the apparatus. Whether it would be sufficiently reliable under the rough daily conditions of boiler working is another matter, but as an effort to deal with a point in connection with smoke prosecutions that nearly always gives rise to contradictory evidence it is worth placing on record. A close study of such a smoke indicator, it may be well to point out, would in any case be a poor substitute for a good CO_2 recorder, of which there are now several reliable types, and an intelligent comprehension of which by the stoker is a better guide to boiler economy than a study of the colour of the smoke.

SELECTION OF MATERIAL FOR CASTINGS.

In a paper on "The Properties, Treatment, and Selection of Iron and Steel for Engineering Purposes," read recently before the Cleveland Engineering Society, Mr. James H. Herron said that in the case of castings that were only subjected to a condition of static loading, and where no limits of space or weight were prescribed, iron castings answered the purpose in every way. They not only offered the easiest problem in castings, but were subject to less shrinkage and were much easier to machine than castings made from other material. For this reason iron castings were satisfactory to use in machine parts and formed the bulk of such castings. There were, of course, conditions of loading where it was not one of static condition, but in a measure dynamic, as in the steam engine, but the rate of change in the stress was uniform, and the reversal of stress took place in an appreciable length of time, so that it might be considered perfectly feasible to use castings of this character if a unit stress was selected sufficiently low. Steam engine builders allowed a very low unit stress on all cast iron. In machine design unit stresses allowed were inversely proportioned to the service expected. Many designers did not exceed a unit stress of 2,000lbs. for ordinary conditions, assuming that the requirement varied from zero to a maximum minus. The compressive stress was usually regarded as negligible. In steam cylinders, or other containers for an elastic fluid, the unit stress was often as low as 400lbs. As a rule castings were subjected to a stress as above given, *i.e.*, from zero to a maximum plus or minus. This condition of loading had not in the past been considered one of dynamic character, but it was, nevertheless. Engineers while not generally recognising such condition allowed for it in the low unit stresses assumed.

Where a greater strength was required than in cast iron the semi-steel casting could, the author observed, be resorted to and seemed to give satisfactory results. There was a question whether semi-steel castings could be depended upon to show a consistent ductility. There were tests of these castings which showed an appreciable elongation, although there was no way from the test or analysis of ascertaining the proportion of steel entering into the mixture.

Where still additional strength was required and a considerable toughness, the malleable casting offered an excellent solution, especially where the castings were small. The malleable casting should not be confused in value with steel forgings, as the only part that was at all ductile was the outside skin. Malleable castings were, in the author's opinion, of about twice the value of grey iron castings.

Where combined strength and ductility were required the steel casting was the only form that could be used where a cast shape was necessary. One of the great objections to steel castings was the danger of superficial blow-holes, so that where a clean finished surface was required it was well to substitute some other form of casting, unless sufficient confidence could be placed in the foundryman to furnish the proper material. There was no question that castings could be made free from blow-holes if proper precaution was taken, and from personal observation by the author both vanadium and titanium treated steel had proved in every way satisfactory for castings. Not only had the steel been free from blow-holes, but it had been rendered much denser by the expulsion of the occluded gases.

Dealing with the proper design of castings, the author stated that these should, if possible, be of uniform cross-section with the corners well rounded and generous fillets in the angles. This was especially the case in steel castings where the shrinkage was large. When iron and steel solidified the crystals forming tended to set themselves normal to the surface, consequently, when the corners were square, a plane of weakness was formed, the plane bisecting the angle at the corner.

The value of the hammer forging was in the mechanical refining which took place throughout the entire mass due to the equal hammering of the forging. In the drop forging the hammer tended to hammer one part of the forging much greater than other parts, resulting in unequal stresses which

tended to either weaken the material or cause a subsequent distortion. With the proper heat treatment a drop forging would be of equal value to the hammer forging provided it had had care in heating for the forging operation. Unfortunately, there was a tendency to overheat the steel to have it conform readily to the shape of the die and to reduce the work involved in forging to a minimum. This was, of course, a great mistake and constituted the chief objection to drop forgings. There was one point in drop forgings that should not be overlooked, namely, that all drop forgings subjected to any very considerable stress should be either annealed or heat treated before use. This was very imperative with gears where they were to be subsequently hardened or tempered and should be done prior to the machining operation, so that the distortion resulting from the annealing operation might be machined out.

A COMBINED VERTICAL AND LOCOMOTIVE BOILER.

THE accompanying illustrations show a design of combined vertical and locomotive boiler, the invention of Mr. E. Pielock, of Landshuterstrasse 14, Berlin. The air for combustion is heated in a chamber having a stepped wall. This chamber is situated between the vertical boiler and the horizontal locomotive boiler, and the air for combustion is conducted through passages and distributed beneath the fire-grate. The combustion gases strike against the stepped wall, heating it to incandescence, and are deprived of floating ashes before passing through the smoke tubes into the smokebox.

Fig. 1 is a longitudinal section of the steam generator;

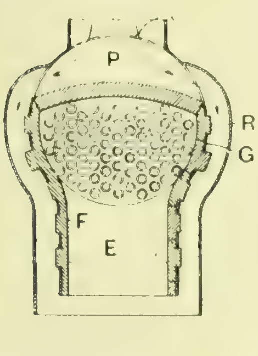


FIG. 2.

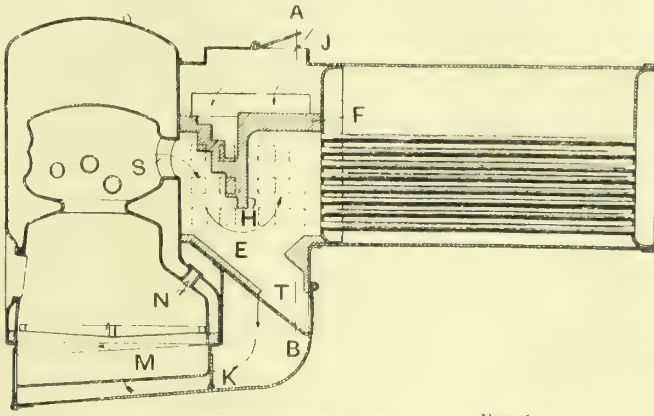
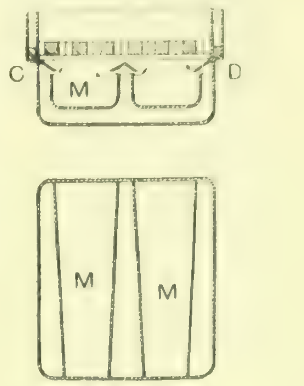


FIG. 1.



FIGS. 3 AND 4.

COMBINED VERTICAL AND LOCOMOTIVE BOILER.

Fig. 2 is a cross-section taken on the line A—B of Fig. 1; Fig. 3 is a cross-section through the fire-grate and ash-pit; and Fig. 4 is a horizontal section taken on the line C—D of Fig. 3. Between the vertical boiler and the horizontal locomotive boiler is the combustion chamber E, in which are contained walls F of refractory material which separate the inner space from the outer walls of the chamber and leave channels G at both sides for the air supply to the grate of the vertical boiler. In the chamber E surrounded by walls F there is a depending wall H in the form of an arch composed of steps facing towards the vertical boiler, the arch being of refractory material and rendered incandescent by the flames from the fire. The lower part of the chamber E receives the ashes separated from the fire gases in striking the arch. The air supply for the grate enters through a closeable aperture J and passes along the channels G and through a door K into channels, built in the ash-pit, and so beneath the grate.

The ash-pit M, shown separately in Figs. 3 and 4, is entirely closed during working, cinders being prevented from falling out and air being supplied from the channels to the sides and the middle of the grate. The passages are tapered, as shown in Fig. 4, so as to widen towards the front of the boiler, *i.e.*, in the direction of the flow of the air, so as to ensure better distribution of the air. The air current can be regulated by means of the door K from the exterior. For the supply of air above the grate there are provided distributing nozzles N along the rear wall of the vertical boiler, these nozzles receiving air from the channels G and being controlled by a slide extending along the entire wall of the firebox. The fire gases in leaving the vertical boiler O have to pass through an opening S of a size calculated to give the smallest cross-section for a desired maximum velocity of the gases so that the latter may strike with great intensity against the arch H. The violent impact with the steps of the arch causes the gases to mix intimately and at the same time to separate out the solids carried with the gases, the solids falling into the collecting space T of the chamber E. With this arrangement complete combustion is, it is claimed, obtained, while emission of burning fuel from the chimney and the choking by ashes of the smoke tubes in the locomotive boiler are practically avoided. The air entering the opening J above the arched roof becomes heated in the space P by the upper brickwork and also by passing along the channels G round the side walls F, the heat being taken up by iron plates arranged between projecting parts R of the brick walls, while at the same time the air cools the walls and so causes same to last longer than they would otherwise.

INTERNATIONAL ENGINEERING CONGRESS, 1915.

AMONG the general subjects to be treated before the International Engineering Congress, to be held at San Francisco, Cal., September 20th to 25th, 1915, probably the one having the broadest interest is that of Materials of Engineering Construction, which enters into all phases of engineering activity. The list of topics which will be treated in this section is as follows: (1) Timber. (2) Preservative Treatment of Timber. (3) Substitutes for Timber in Engineering Construction. (4) Brick in Engineering Structures. (5) Clay Products in Engineering Structures. (6) Probable and Presumptive Life of Concrete Structures made from Modern Cements. (7) Aggregates for Concrete. (8) Slag Cement. (9) Waterproof Concrete. (10) Cements containing Additions of Finely Ground Foreign Material. (11) Economics of the World's Supply of Iron. (12) The Life of Iron and Steel Structures. (13) The Employment of Special Steel in Engineering Construction. (14) The Place of Copper in the Present Engineering Field, and the Economics of the World's Supply Thereof. (15) Alloys and Their Use in Engineering Construction. (16) Aluminium in Engineering Construction. (17) The Influence of the Testing of Materials upon Advances in the Designing of Engineering Structures and Machines. (18) Cement Testing. (19) Testing of Metals. (20) Testing of Full-sized Members. (21) Proof Testing of Structures. The papers to be presented from the United States have already been arranged for from the recognised leading authorities on the various topics. Arrangements for the papers from foreign authors are being rapidly concluded, and the aggregation of papers which will be presented will constitute a broad review of the field and be of the highest value. Marked interest in the Congress from foreign countries continues, and there is every evidence that the attendance from abroad will be large. Full information concerning the Congress, the price of subscription, and the arrangement for purchase of volumes of the proceedings, may be obtained by addressing the Committee of Management, International Engineering Congress, 1915, Foxcroft Building, San Francisco, Cal., U.S.A.

INTERNAL STRAINS IN COLD-WROUGHT METALS, AND SOME TROUBLES CAUSED THEREBY.*

BY PROF. E. HEYN.†

(*Concluded from page 529.*)

IN forgings sometimes defects occur as illustrated in Figs. 22 and 23. Fig. 22 refers to a hot-forged piston rod made of malleable brass (about 40 per cent. of zinc). It broke after a very short period of working, one of the fractured pieces showing a hollow cone II (indicated by the broken lines in the figure), the other a cone I, fitting into the hollow II. The two parts I and II were separated from each other by an intervening space, and were coherent only within a small annular area of the thickness d. This latter being unable to



FIG. 22.

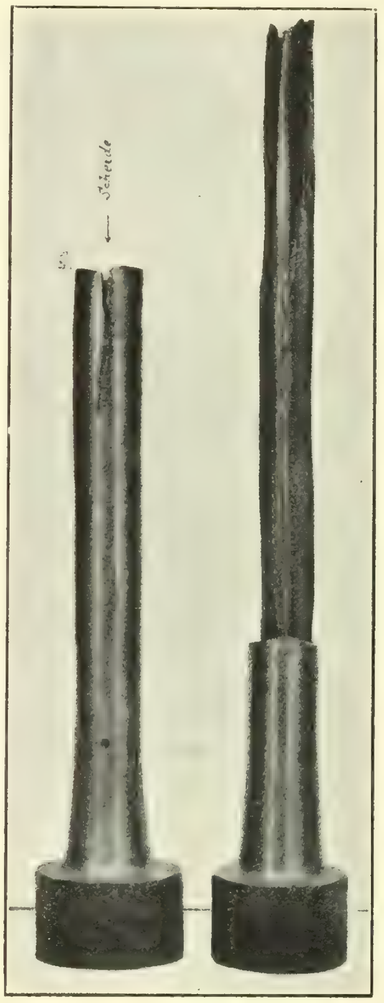


FIG. 23.

bear the working load to which the piston rod was subjected, failure was sure to ensue. There was in the appearance of the rod, even after finishing on the lathe, not the least indication of the dangerous internal fracture. The same applies to the tensile test-bar in Fig. 23. It had been machined in the ordinary way, showing no sign of any irregularity. Pulled in the testing machine, it broke at a very low load into three pieces, two of which are reproduced in Fig. 23. They fit into each other like a dagger into its sheath.

In order to give the explanation of the phenomena stated in the preceding paragraph, attention must be directed to the following well-known experiment. A round bar of soft steel was hammered in the cold under a rapidly acting machine-hammer, the bar being uninterruptedly turned round its axis. The mutual position of hammer and bar is shown in Fig. 24. The effect was a longitudinal crack rr in the axis of the bar, as shown in Figs. 24 and 25. If we consider a cross-section through the bar (Fig. 24, right hand), the outer layer a is directly influenced by the blows of the hammer and is therefore stretched more severely than the central core i, which acts like an anvil. Hence the ring a tends to increase its diameter, whilst the core opposes this tendency, being itself subjected to radial strains in an outward direction. When the hammering is continued to a sufficient degree the stresses set up may exceed the resisting power of the material. Since the stresses are greatest in the axis, internal fracture will be produced in this axis along the line rr in Figs. 24 and 25. Hot-forging may lead to similar results when the work is done under a hammer of too small a weight falling with great velocity, or when the bar was unequally heated before forging.

Whilst in the example referred to in Figs. 24 and 25 the ultimate tensile strength was exhausted in a direction crosswise to the axis of the bar, giving rise to a longitudinal crack, it is also possible that, in consequence of the more pronounced effect of stretching in the superficial layers as compared with the inferior effect in the core, the longitudinal stresses may reach the tensile limit, which must lead to internal transverse fractures within the core. On hammering being continued, these fractures assume a cuplike shape on account of the unequal stretching in the different layers in various distances from the axis. Finally the fractures show the appearance illustrated in Figs. 22 and 23.

Let us now consider the question whether and to what degree the indications of the ordinary tensile test may be affected by internal strains, for instance, by those due to cold-working. Above all, it is important to know whether the tensile test gives the correct amounts of the limit of proportionality, of the yield-point, the correct relation between stress and strain in test-pieces affected by internal stresses.

Let—

$f_{\rm I}$ be the sectional area of the outer layer I in Fig. 3.

$f_{\rm II}$,, ,, central core II ,,

$$f = f_{\rm I} + f_{\rm II}.$$

$+\sigma o_{\rm I}$ be the internal stress (tension) in I.

$-\sigma o_{\rm II}$,, ,, ,, (compression) in II.

$+\epsilon o_{\rm I}$,, elastic elongation per unit of length in I, brought about by stress $+\sigma o_{\rm I}$.

$-\epsilon o_{\rm II}$ be the elastic compression per unit of length in II brought about by stress $-\sigma o_{\rm II}$.

E be the modulus of elasticity.

σ ,, stress reckoned per unit of sectional area.

ϵ ,, strain per unit of length, measured between marks on the test-bar under a load producing stress σ.

Let us assume that core II has undergone more severe cold-stretching than the outer layer I, which, as was stated above, leads to internal tension stress $+\sigma o_{\rm I}$ in I, and internal compression stress $-\sigma o_{\rm II}$ in II. In order that equilibrium may be established between the forces $\sigma o_{\rm I} f_{\rm I}$ and $-\sigma o_{\rm II} f_{\rm II}$, the equation

$$\sigma o_{\rm I} f_{\rm I} - \sigma o_{\rm II} f_{\rm II} = o$$

must be fulfilled, consequently

$$\frac{\sigma o_{\rm I}}{\sigma o_{\rm II}} = \frac{f_{\rm II}}{f_{\rm I}},$$

or, since $\sigma o_{\rm I} = {\rm E}\epsilon\sigma_{\rm I}$ and $\sigma o_{\rm II} = {\rm E}\epsilon o_{\rm II}$,

$$\frac{\epsilon\sigma_{\rm I}}{\epsilon\sigma_{\rm II}} = \frac{f_{\rm II}}{f_{\rm I}}.$$

In Fig. 26, in which the strains ϵ (reckoned per unit of length) are plotted as abscissæ and the stresses ϵ (reckoned per unit of sectional area) as ordinates, the original state of the two portions I and II in the bar, before external load is applied, is characterised by the points C and D, OC indicating the internal tension stress $+\sigma o_{\rm I}$, and OD the internal compression stress $-\sigma o_{\rm II}$. If the two portions I and II were separated from each other, so that each could assume its natural length, the portion I would shorten elastically by the amount OA $= \epsilon o_{\rm I}$, whereas the core II would extend elastically by the amount OB $= \epsilon o_{\rm II}$, the points A and B representing the stress-free state of the portions after separation.

Let us now suppose the bar (I and II combined, and self-strained) to be subjected to the load P_1, giving rise to an increase λ_1 of the distance l of the two gauge-marks on the

* May lecture delivered before the Institute of Metals, May 12th, 1914.

† Royal Technical Institute, Charlottenburg, and Director of the Royal Prussian Institute for Testing Materials, Berlin—Lichterfelde.

surface of the bar and consequently to an additional strain $\epsilon_I = \frac{\lambda_I}{l}$, then the total strain in portion I will be $\epsilon_I = \epsilon o_I + \epsilon_I = AE$, the total strain in core II $\epsilon_{II} = \epsilon_I - \epsilon o_{II} = BE$. The corresponding stresses are $\sigma_I = EF$ and $\sigma_{II} = EG$. The curves I and II in Fig. 26 are assumed to represent the true relation between strain and stress in the portions I and II of the bar. On account of the modulus of elasticity being the same in I and II, the two curves will be parallel within the elastic ranges AH and BF respectively. On the assumption that the core II is more severely cold stretched than portion I, the yield point F in the former will, according to a law generally accepted, be raised by the process of cold working above the yield-point H of the portion I, which received less cold work.

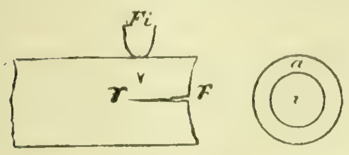


FIG. 24.


FIG. 25.

From the curves I and II it is possible to find the curve M giving the relation between the strains $\epsilon = \frac{\lambda}{l}$ (λ being the change of the distance l of the gauge-marks on the surface of the bar) and the stresses $\sigma = \frac{P}{f}$ (where P is the external load applied and f the sectional area of the bar).

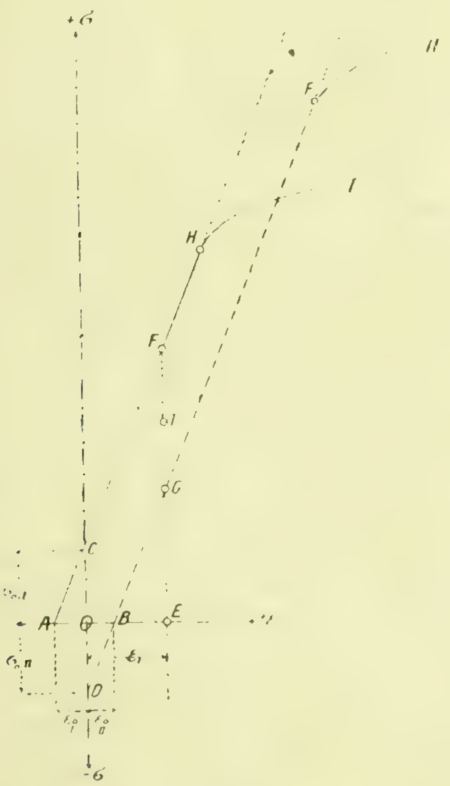


FIG. 26.

Under the load $P = 0$, the change λ of the gauge distance and consequently the amount of ϵ is equal to zero. Hence the curve M must take rise in the origin O of the system of co-ordinates. A definite external load P_1, involving the strain ϵ_1 measureable by the change λ_1 of the gauge-length, gives rise to the stress $\sigma_I = EF$ in portion I and $\sigma_{II} = EG$ in core II, and to the average stress σ_1 in the total section f of the bar, $\sigma_1 = \frac{P}{f}$. For equilibrium we must have

$$\sigma f = \sigma_I f_I + \sigma_{II} f_{II},$$

$$\sigma_1 = \sigma_I \frac{f_I}{f} + \sigma_{II} \frac{f_{II}}{f}.$$

σ_1 is represented by the ordinate EI of the curve M, provided that the point I in Fig. 26 is located so that $FI = \frac{f_{II}}{f} FG$ and $GI = \frac{f_I}{f} FG$. The proof is as follows:—

$$EI = EG + GI = EG + \frac{f_I}{f} FG$$

$$= \sigma_{II} + \frac{f_I}{f}(\sigma_I - \sigma_{II});$$

$$EI = \sigma_I \frac{f_I}{f} + \sigma_{II} \frac{f - f_I}{f},$$

$$EI = \sigma_I \frac{f_I}{f} + \sigma_{II} \cdot \frac{f_{II}}{f},$$

consequently

$$EI = \sigma_1.$$

By proceeding in the same manner for different loads P_2,

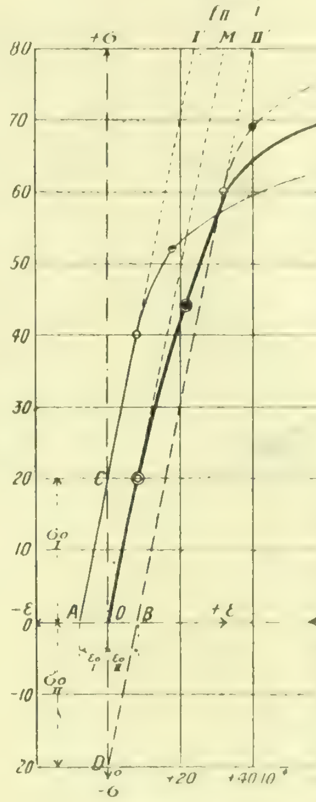


FIG. 27.

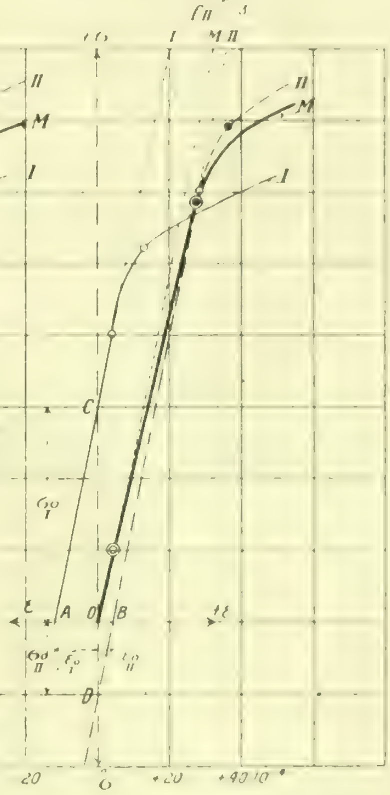


FIG. 28.

P_3 . . ., and strains $\epsilon_1, \epsilon_2, \epsilon_3$ . . . the points 1, 2, 3 . . . of the curve M may be traced as in Figs. 27 to 29.

The curve M is the direct result of the tensile test. The comparison of the three figures shows how this result will be affected by the presence of internal strains. In these figures it is assumed that the sum of the internal strains $\epsilon o_I + \epsilon o_{II}$ is kept invariable, and that only the ratio $\frac{f_I}{f_{II}}$ of the sectional areas of the portions I and II varies from 1 : 1 in Fig. 27 to 1 : 3 in Fig. 28 and 3 : 1 in Fig. 29. The shape of the curves I and II is supposed identical in all three cases, only the position of the points A and B with respect to the origin O varies as the ratio $\frac{f_I}{f_{II}}$. The ordinates of H and F, in which the curves I and II begin to deviate from the elastic lines I′ and II′, represent the respective limits of proportionality σP_I (= 40*) and σP_{II} (= 60*) of the material in the portions I and II.

* Expressed in arbitrary units.

Though these limits are supposed to be invariable in the three cases shown in Figs. 27 to 29, the corresponding limits σP_M in the curves M found experimentally by the tensile test may differ widely. Thus in the case of Fig. 28 the limit σP_M lowered to about 10,* to 20 in Fig. 27, and to 30 in Fig. 29.

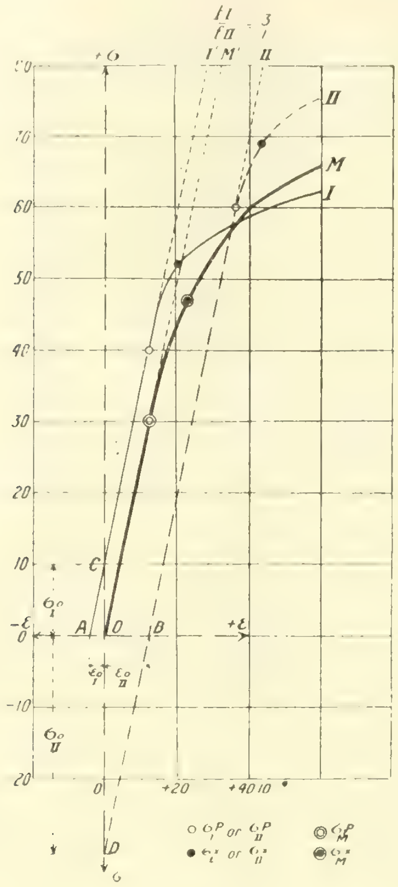


FIG. 29.

Next let us consider the amount of the stresses σx producing a permanent set x, or to put it in other words, the stresses giving rise to strains indicated by the abscissæ of the curves I, II, and M exceeding those corresponding to the finely dotted straight lines I′, II′, M′ by the amount x. Assuming x to be $4 \cdot 10^{-4}$ (in arbitrary units), the stresses σx in the portions I and II are $\sigma x_I = 52$* and $\sigma x = 69$. The experimental curves M will indicate the following amounts of σx: in the case of Fig. 27 ($f_I : f_{II} = 1:1$) $\sigma x_M = 44$, in Fig. 28 ($f_I : f_{II} = 1:3$) $\sigma x_M = 58·5$, and in Fig. 29 ($f_I : f_{II} = 3:1$) $\sigma x_M = 47$.

* Expressed in arbitrary units.

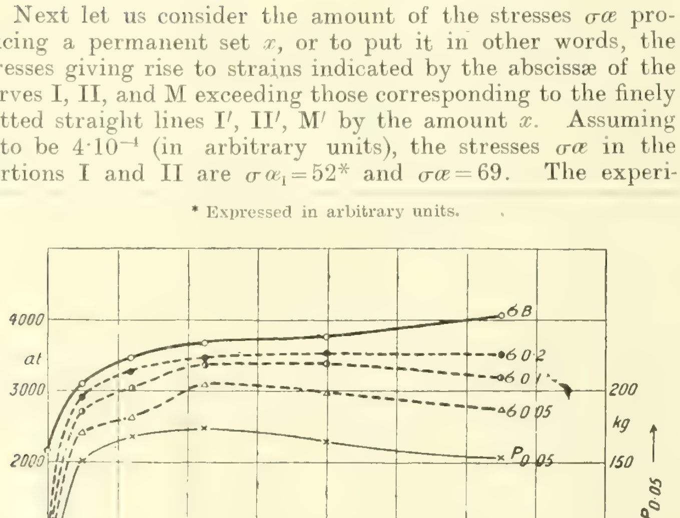


FIG. 30.—INFLUENCE OF COLD-ROLLING ON THE STRENGTH PROPERTIES OF COPPER SHEET.

Electrolytic Copper Remelted Sn=0; Pb=0; Sb=0; As=0; Bi=0; Fe <0·01; Al, traces; Zn, traces; Cd=0; Ni, traces; S <0·01; O=0·10 per cent.

σB = Ultimate tensile stress in kilogrammes per square centimetre.

$\sigma 0·2$, $\sigma 0·1$, $\sigma 0·05$ — Stresses in kilogrammes per square centimetre producing a permanent set of . . . . . 0·2 per cent., 0·1 per cent., 0·05 per cent.

P0·05 Ball-pressure hardness according to Martens-Heyn: pressure in kilogrammes producing a permanent impression of 0·05 millimetre of a 5-millimetre ball.

$f_0 : f$ Ratio of the sectional areas of the sheets before and after cold-rolling.

From the above can be seen that the values of the limit of proportionality, σP_M, or those of any other limit, σx_M, as found by the tensile test, must be highly dependent upon the amount of internal stresses and upon their distribution over the sectional area of the bar tested. It is even possible that the limits σP_M and σx_M, which, according to a law well established, are raised by cold-work, may appear depressed instead of raised, because the effect of cold-work, as indicated by the tensile test, may be completely masked by the above-mentioned effect of internal strain.

This affords an explanation for the curious fact shown in Fig. 30, which has reference to cold-rolled copper sheets. A sheet of hot-rolled copper 7·5 mm. in thickness was successively cold-rolled to 5 mm., 3·4 mm., 2·3 mm., 1·5 mm., 1·0 mm. in thickness without intervening reheating. The corresponding ratios f_0/f of the original section f_0 before cold-rolling to the section f after cold-rolling are 1·5, 2·21, 3·26, 5, 7·5, and are plotted as abscissæ in Fig. 30. The ordinates represent the ultimate tensile strength σ_B (in kilogrammes per square centimetre), the limits $\sigma_{0·2}$, $\sigma_{0·1}$, $\sigma_{0·05}$ (stresses in kilogrammes per square centimetre giving rise to a permanent set of 0·2, 0·1, 0·05 per cent. respectively), and the ball-pressure hardness $P_{0·05}$ in kilogrammes.

Inspection of Fig. 30 shows that with increasing amount of cold-rolling the limits $\sigma_{0·2}$, $\sigma_{0·1}$, $\sigma_{0·05}$, and the hardness $P_{0·05}$, first rise to a maximum value, after which there is a marked decline. The latter behaviour would seem quite abnormal, if it were not explained by the influence of the internal strains as set forth above.

I venture to say that perhaps a good deal of former research work carried out with a view to elucidating the effect of cold-work on the properties of metallic materials has been baffled by that mysterious influence of internal strain which has just been explained.

In conclusion, I wish to express the hope that the line of research touched upon in this lecture may be pursued in order to elucidate and dissipate, more than I could do myself, the manifold hidden dangers entailed by internal strains in the mass of structural members.

INTERNAL-COMBUSTION ENGINES FOR POWER GENERATION AT COLLIERIES.*

BY JOHN DAVIDSON.

IN the early days steam engines were practically the only prime movers possible, but since the advent of electrical transmission it is generally recognised that the most efficient and best scheme to adopt is to put down one large generating station, and to operate the various auxiliaries electrically. In the end this minimises the amount of attention required, and gives a flexibility which is impossible under any other system in vogue at the present day. The most economical prime mover is the internal-combustion engine, which is admirably suited for colliery work. In cases where inferior coal is available, it can be used most economically in gas producers of the recovery type; and where the total power required is considerable, the return for the by-products reduces the cost of gas to a negligible quantity. Where by-product coke ovens are in use, the surplus gas can be used to the greatest advantage in the gas engine; and, of course, for ironworks the most economical use for the blastfurnace gas is in this form of prime mover. Against all this it will doubtless be argued that the gas from recovery producers can be used for generating steam in boilers to drive steam engines or turbines, and also that coke-oven gas can be used in a similar manner; but the fact is indisputable that gas can be used in internal-combustion engines far more efficiently than in any other way. Tables I. to V. show the running costs for: (*a*) A steam turbine plant with coal-fired boilers. (*b*) A steam generating plant as above, but with the boilers fired by recovery-producer gas. (*c*) A plant driven by a gas engine with recovery producer. (*d*) Coke-oven gas burnt under steam boilers with a 2,000 b.h.p. turbine plant. (*e*) Coke-oven gas used in a gas engine.

* Abstract of paper read before the Institution of Mining Engineers, June 4th, 1914.

TABLE I.—*Steam-turbine Plant with Coal-fired Boilers. Capital Costs (Buildings not included).*

Item	£
2,000 b.h.p. of steam turbines	£8,000
2,000 b.h.p. of steam boilers	3,500
Total capital cost	£11,500

Running Costs (7,200 hours per annum).

Item	£
10,700 tons of coal at 12s. per ton	£6,420
Oil and stores	700
Labour	1,010
Maintenance at 2 per cent.	230
Interest and depreciation at 10 per cent.	1,150
Total running cost per annum	£9,510

Cost per brake horse-power hour 0·159d.

Equivalent cost per unit generated 0·238d.

TABLE II.—*Steam-generating Plant with Boilers Fired by Recovery producer Gas.*

Capital Costs (Buildings not included).

Item	£
Recovery gas plant and boilers	£23,250
2,000 b.h.p. of steam turbines	8,000
Total capital cost	£31,250

Running Costs (7,200 hours per annum).

Item	£
20,600 tons of coal at 12s. per ton	£12,360
Sulphuric acid for sulphate plant	1,200
Oil and stores	875
Bags and packing sulphate	270
Labour	1,950
Maintenance at 2 per cent.	615
Interest and depreciation at 10 per cent.	3,125
Total running cost per annum	£20,395

Credit.

Item	£	£
Sulphate	£10,000	
Tar	600	10,600
Net running cost per annum		£9,795

Cost per brake horse-power hour = 0·163d.

Equivalent cost per unit generated = 0·244d.

TABLE III.—*Plant driven by a Gas Engine with Recovery Producer.*

Capital Costs (Buildings not included).

Item	£
Gas engine generator complete	£11,880
Recovery gas plant	8,100
Total capital cost	£19,980

Running Costs (7,200 hours per annum)

Item	£
8,840 tons of coal at 12s. per ton	£5,304
Sulphuric acid for sulphate plant	522
Oil and stores	645
Bags and packing sulphate	116
Labour	1,276
Maintenance at 2 per cent.	398
Interest and depreciation at 10 per cent.	1,998
Total running costs per annum	£10,259

Credit.

Item	£	£
Sulphate	£4,350	
Tar	261	
		4,611
Net running cost per annum		£5,648

Cost per brake horse-power hour 0·094d.

Equivalent cost per unit generated 0·141d.

TABLE IV.—*Coke-oven Gas burnt under Steam Boilers with a 2,000 b.h.p. Turbine Plant.*

Capital Costs (Buildings not included).

Item	£
2,000 b.h.p. of steam turbines	£8,000
Gas-fired boiler	4,000
Total capital cost	£12,000

Running Costs (7,200 hours per annum).

Item	£
Gas value assumed at 2d. per 1,000 cub. ft. at 450 B.Th.U. per cubic unit	£5,350
Oil and stores	500
Labour	180
Repairs and maintenance at 2 per cent.	240
Interest and depreciation at 10 per cent.	1,200
Total running cost per annum	£7,770

Cost per brake horse-power hour 0·129d.

Equivalent cost per unit generated 0·193d.

TABLE V.—*Coke-oven Gas used in a Gas Engine. Capital Costs (Buildings not included).*

Item	£
2,000 b.h.p. gas engine and generator complete	£11,880

Running Costs.

Item	£
Gas value assumed at 2d. per 1,000 cub. ft. at 450 B.Th.U. per cubic feet	£2,800
Oil and stores	500
Labour	312
Repairs and maintenance at 2 per cent.	236
Interest and depreciation at 10 per cent.	1,188
Annual running costs per annum	£5,036

Cost per brake horse-power hour = 0·084d.

Equivalent cost per unit generated 0·126d.

The running costs given in the tables are based upon full load rating, and there will be a variation in efficiency according to the load factor. The gas consumption per unit generated does not vary much from the smallest to the largest engine, and by judiciously arranging the size of the units so that they can be run at or near their full rated output, maximum efficiency can be obtained. The figures quoted for the price of fuels, &c., will vary slightly according to the districts in which the plant is installed, but the tables may be taken as generally representing the running cost for plants driven in the various manners named.

Economical as the generation of power by gas engines proves to be, there is still another source by which the overall efficiency can be increased, and that is by the use of boilers heated with the exhaust gas from the engines. The use of such boilers is now becoming general, and they will evaporate, roughly speaking, from 2¼lbs. to 2½lbs. of water per brake horse-power developed by the engine. When these figures are considered in connection with a large unit, the saving per annum is a notable sum.

The utilisation of coal gas—principally from coke ovens having a calorific value of from 400 to 450 B.Th.U. is receiving more and more attention, and this gas—although somewhat richer in hydrogen than ordinary town gas—is an excellent one for use in gas engines. It is perhaps somewhat strange that more use has not been made in the past of surplus coke-oven gas, and, generally speaking, of gas engines in connection with colliery work.

In the case of coke-oven gas the greater percentage of hydrogen makes the gas more explosive than is the case with producer and blastfurnace gas. Owing to this, much trouble was experienced in the early days, due to instability in running caused by pre-ignition. The same result can often be noticed with producer plants when an excessive amount of hydrogen is allowed to enter the gas, due to bad manipulation of the gas plant. In this connection it may be mentioned that many makers attempted to use high compression—principally with the object of obtaining maximum economy—whereas the writer believes that if reliability had received first consideration, the large gas-engine business of this country would have been in a better position than it is at the present time. With coke-oven gas, or any gas rich in hydrogen, it is impossible to run engines smoothly and with absolute reliability if the compression is high; and, generally speaking, it is neither necessary nor advisable to have a compression exceeding 90lbs. to 100lbs. per square inch. The question is simply one of design and a proper proportioning of the mixture. In this country there are now a number of plants which have been in successful operation for several years, but undoubtedly coke-oven gas could be used to a much larger extent than it is at present.

Owing to failures during the development stages in the

early days, managers still hesitate to install large gas engines, but the vertical type, which has been most developed in this country, has long since passed the experimental stage. The vertical type is the one most suited for direct connection to electric generators, owing to the possibility of running at fairly high speeds. In a few cases electric generators have been coupled direct to slow-speed horizontal gas engines; but this is rather an expensive arrangement, and seems a somewhat retrograde step, considering the high state of perfection to which the high-speed vertical sets have been developed. The absolute reliability of the high-speed forced-lubrication enclosed steam engine has been demonstrated by thousands of examples; consequently, it is to a similar type of gas engine that the colliery manager will naturally look in the future for driving electric generators for his power station.

In this paper the writer has refrained from discussing the question of 2-cycle versus 4-cycle engines. At the present time the tendency throughout the world in connection with the internal-combustion engine appears to be along the lines of the 2-cycle; and, as the 2-cycle double-acting engine has already been developed and manufactured in the country for over 12 years, and proved to be an absolutely reliable machine, the writer does not propose to enter into the details of the same beyond stating that the 2-cycle double-acting engine gives an equal turning moment to that of the steam engine, and enables one to build engines of high power, with cylinders and pistons of comparatively small dimensions.

It may be of interest to mention that the early high-speed steam engines were of a somewhat complicated type, and mostly single-acting. The high-power gas engines as made in this country are also of the single-acting type, with one exception, yet the single-acting type will undoubtedly be extinct in the course of a few years. The high-speed steam engine of the single-acting type was a silent-running machine, and, after the initial troubles had been overcome, it proved to be reliable. But, so soon as the double-acting forced-lubrication engine was introduced, the fate of the single-acting engine was sealed. During its development, the high-speed steam engine passed through many stages, but in the end simplicity was the prime characteristic—hence its absolute reliability. The high-speed steam engine was primarily designed to drive electric generators, and as electric transmission of power has now become practically universal, so the high-speed vertical gas engine is the one to which we must look in the future. For reliability in running simplicity must be its principal characteristic, and, owing to the fact that the size of units required will increase as time goes on, the double-acting engine will be the one which will eventually hold the field.

There are only a few makes of high-power vertical engines, and those of tandem type are limited in size to about 1,500 b.h.p. As some of these engines have no less than 12 cylinders, we cannot look for much further development in this direction. Owing to the multiplicity of cylinders, and the enormous number of valves, springs, cams, and operating mechanism generally, the complication becomes ridiculous. The main object in the multiplicity of cylinders has been to avoid the water cooling of pistons; but the cooling of pistons has now been in use with absolute reliability, even in connection with high-speed engines, for a number of years.

The single-acting engine just mentioned has also another defect, in that it is impossible to control with any degree of certainty the supply of lubricating oil to the cylinders. Where engines of high power are in continuous service, lubricating oil becomes an item for careful consideration—not only on account of its cost, but owing to the frequent necessity for cleaning out the cylinders. Isolated cases can be found where single-acting engines have run for some months without any grinding-in of valves, or of stopping to clean out the cylinders and pistons; but in the case of double-acting engines, where the supply of oil is entirely independent of the splash in the crank chamber, engines have run for periods of two years without any necessity of cleaning the cylinders. This type of engine is therefore the one to be adopted, if continuous service and reliability are required.

The writer will now consider for a moment what are the weak points of gas engines. One of the weak points in connection with large single-acting vertical gas engines is the frequent necessity for cleaning out the cylinders. So long as the pistons are exposed to the underside of the crank case, this difficulty cannot be overcome efficiently, as there is no means of controlling the amount of oil which passes up from the crank chamber. Another weak point is the burning and failure of the exhaust valves, which require occasional cleaning and grinding-in, and many failures are still experienced because of the breakage of valves. Another weakness is in the ignition gear, although, generally speaking, it must be admitted that failures from this cause are few and far between, provided, of course, that a modern reliable gear is fitted to the engine in the first instance. From the available statistics one infers that the freedom from breakdown in gas engines is very encouraging, and the weaknesses just mentioned may be looked upon as the only ones that are liable to cause occasional stoppage.

For long continuous work, an engine which is simple in construction is the one most likely to prevail in the end. The tendency in development has been towards simplicity; but, as already mentioned, for large owners (owing to the prevalent desire to use air-cooled pistons) multi cylinder engines, mostly of the tandem form, have found favour among engine builders, although this can hardly be said to be in the direction of simplicity. If the engines are made on steam-engine lines, with double acting two cycle cylinders, the size of the working piston need be only about a quarter of that of the four-cycle single-acting type, and for the same power the strains are proportionately less; both these points are very advantageous in the case of large engines. In the case of single-acting engines, the pistons are usually called upon to serve as the crossheads; and, although they appear to wear exceedingly well, this type will doubtless in the near future be obsolete. The writer believes that the double-acting two-cycle engine, built on substantial lines, will be the one that will ultimately be used by all large vertical engine builders.

Accessibility is of prime importance, and in modern engines this point has received most careful consideration. Even in vertical tandem engines we are informed that it is possible to open up and get at the lower piston within 40 minutes on a 1,000 h.p. engine. This speaks very well for the design. For long continuous work it is also of great importance that the bearing and working surfaces should be liberal, and the strength of the parts most carefully proportioned to resist the work which they are called upon to bear. Generally speaking, the old type of low-tension ignition gear still finds favour, but for reliability and minimum number of parts likely to give trouble, the high-tension magneto cannot be excelled. The sparking plugs, even with this type of gear, require renewal from time to time, but this is not a costly item. With the high-tension magneto the minimum attention is required, and there are no batteries to charge.

For continuous heavy service much has been stated with regard to the reliability of the gas engine, but the colliery manager must give careful attention to the production of gas if he expects reliability in his engine. In the case of boilers, softening plants have often to be installed; in a similar way, in connection with gas producers and coke ovens, suitable cleaning and purifying appliances must be used. Sulphur has to be dealt with drastically, especially where big engines are installed, as in all these cases pistons and rods are of necessity water cooled. In many cases too liberal a supply of water is used for the pistons, due to the attendant's exaggerated anxiety to feel safe, and acid fumes are condensed on the cool rods, causing corrosion. Again, any leakage of water into a cylinder with sulphurous gas will cause trouble, so that great care should be taken in dealing with this matter. Dust also forms a difficulty which requires consideration, but this is one that causes very little anxiety in the ordinary way nowadays.

While speaking of large gas engines the writer has referred only to the vertical engine, as this appears to be the type most favoured and undoubtedly most suitable for direct connection to electric generators; but the horizontal engine is still favoured by mill engineers, and for blowing engines, air compressing, and water pumping, through the medium of a tail-rod, it may still possess a useful sphere of work. Air compressors of the vertical high-speed type, however, are rapidly superseding those of the horizontal type throughout the country, and therefore it is very probable that gas-driven air compressors of the vertical type will also be favoured in the near future.

DAVEY'S INTERNAL-COMBUSTION PUMPING ENGINE.

A PATENT recently granted to Mr. Henry Davey, of Conaways, Ewell, Surrey, relates to pumps in which the power is obtained by internal combustion in an engine cylinder, and has for its object to construct a non-rotative internal combustion pumping engine of high efficiency. In the Cornish pumping engine and in the Davey differential pumping engine the inertia of the moving mass enables the steam to be used expansively on the piston, and in the design under notice the pressure caused by internal combustion in an

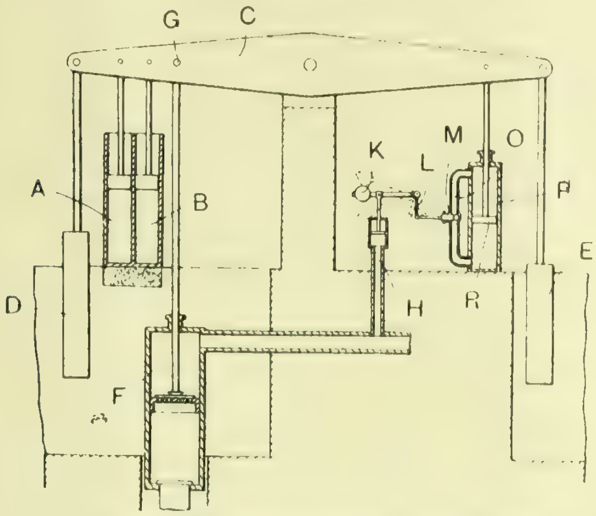


FIG. 1. DAVEY'S INTERNAL-COMBUSTION PUMPING ENGINE.

engine cylinder is similarly used. Fig. 1 is a vertical section of the pumping engine; Figs. 2 and 3 are diagrams illustrating the theory of the engine; Fig. 4 is a section through the end of the cylinder, showing one method of operating the exhaust valve; and Fig. 5 is a section of an improved form of displacer.

The engine cylinders A B working on the Otto cycle are arranged side by side, and have their pistons connected to a beam C. At the ends of the beam there are supported weights D, E, the weight D being larger than the weight E. The pump cylinder F is provided with a piston connected to the beam at the point G, between the end and the fulcrum. Connected to the discharge side of the pump there is a pipe H, in which a piston works against the action of a weight K, the piston being connected by a lever L with a plunger M, adapted to close the communication through the pipe O between the two ends of the cylinder P, in which the piston R connected to the beam works.

The diagram Fig. 3 represents what takes place in the cylinder of the Cornish engine, in which the steam puts in motion a mass, the inertia of which equates the steam pressures which fall from a high to a low pressure, and the

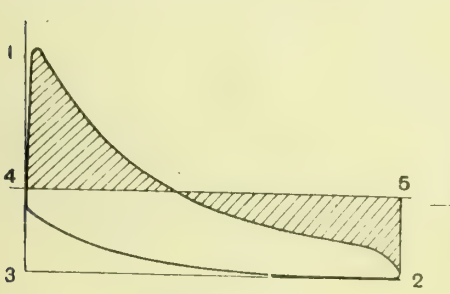


FIG. 2.

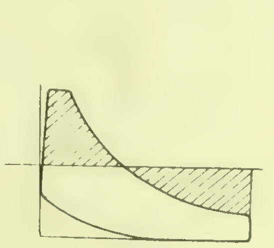


FIG. 3.

pump resistance, which is constant. During the return stroke the energy of the moving mass is absorbed in compressing steam into the clearance space behind the piston. The diagram Fig. 2 is a similar diagram applied to the new engine. In this case the pressure of explosion puts in motion a mass, the inertia of which equates the power and resistance in a similar manner, and on the return stroke the energy of the moving mass is absorbed in compressing the explosive charge into the clearance space behind the piston. The work done by the working fluid is represented by the area 1, 2, 3, 1, while the resistance of the pump is shown in the diagram by the area 3, 4, 5, 2. The moving mass by its inertia equates the two diagrams, and the relationship between the pumping load on the engine and the mass to be put in motion determines the maximum velocity of the piston during the stroke. During the down-stroke of the working piston the excess weight at D over that at E produces the compression by storing energy in the moving mass at the early part of the stroke and equating the force and resistance by the inertia of the mass. By using a beam for coupling the engine to the pumps the relative strokes of the engine moving mass and pump may be varied to suit the particular application of the engine. In mining engines with spear rod pumps the mass only becomes great and it is not necessary to provide additional weights to get the required inertia. During the return stroke the explosive mixture which was taken into the second cylinder during the explosion stroke of the first cylinder is compressed and then fired, and the cycle of operations is repeated.

A method of operating the exhaust valve of the engine is shown at Fig. 4. In this arrangement, when the piston A is at the top of its explosion stroke it uncovers a port B under the piston C, which is forced up by the pressure in the cylinder moving the lever D to release the catch E and allow the weight on the lever F to drop, opening the exhaust valve G by means of the projecting arm H. When the piston A reaches the end of its down-stroke it is caused by any convenient means to push down the end J of the lever F and allow the exhaust valve to close under the action of the spring K. A spring L is provided, causing the lever D to make the required engagement and to hold up the weight. The exhaust valve will then remain closed until the piston has again reached the upper end of its stroke at a time when

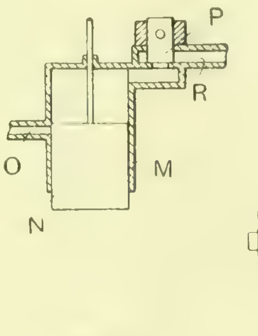


FIG. 5.

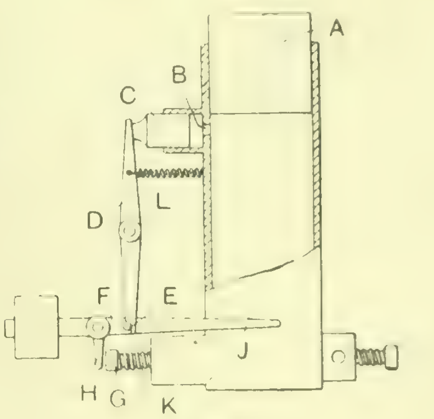


FIG. 4.

pressure exists in the cylinder, and this will not occur until the second stroke after the explosion, *i.e.*, on the next explosion stroke, so that the Otto cycle is properly completed. In order that a constant explosive mixture may be supplied, a displacer (Fig. 5) for gas admission is employed. This may be worked from the engine in any convenient manner, and comprises a cylinder M and piston N. The gas supplied passes in through the passage O, and the piston N moves below this passage, taking in gas. During the up-stroke the piston N passes over the passage O and displaces the gas through the non-return valve P, from which it passes by the pipe R to the engine.

It will be seen that when the head of water against the pump varies the power may be varied by varying the supply of gas and air, as is done in rotary gas engines, and the speed of pumping may be varied by allowing a pause at the end of the compression stroke before firing. In order to stop the engine when the load falls off, the damping cylinder P (Fig. 1) is provided, having its piston R connected to the beam. When the pressure in the pipe H falls the weight K drops, causing the plunger M to stop the passage O, and prevent flow of liquid from one side of the piston R to the other, thus putting a brake on the engine.

THE TALBOT PROCESS IN COMPARISON WITH OTHER OPEN-HEARTH REFINING PROCESSES.*

BY DR. FRIEDRICH SCHUSTER (WITKOWITZ).

(*Concluded from page 536.*)

The Talbot Furnace.—As soon as the entire contents—200 tons—of the Talbot furnace have attained the desired composition, about 65 tons of steel are run off into the ladle and finished in the latter with the addition of liquid ferro-manganese. The residual (approximately) 135 tons of steel retained in the furnace remain covered with a coating of slag approximately 10 mm. to 15 mm. thick. After closing the tap hole and making the necessary repairs on the slag line, the necessary quantities of ore and lime for the next charge are introduced by the charging crane. At the end of 15 to 20 minutes these additions have been sufficiently heated up to allow the contents of the first ladle, holding roughly 30 tons of mixer iron, to be poured into the furnace, considerable reaction then taking place between the ore and the mixer iron; the carbon content of the latter is oxidised, carbon monoxide being liberated. At this stage the evolution of gas is often so considerable that the air has to be shut off and the doors opened, so as to reduce the pressure in the furnace. In spite of the violence of this reaction the bath cools down appreciably, since the above-mentioned reaction is strongly endothermic. After about half an hour, however, the bath quietens down sufficiently to allow of the introduction of a second ladle of mixer iron, a slight reaction generally occurring. The furnace is now rapidly heated up until the charge is completely melted.

The carbon content of the finished steel bath varies between 0·07 and 0·8 per cent., according to the products required, the manganese being about 0·3 per cent. and the phosphorus between 0·02 and 0·03 per cent. The major portion of the slag formed is poured off to the side of the working platform, the charge being finished in the usual manner by the addition of the necessary ore and lime.

The duration of the heat varies, with the same percentage of scrap, according to the phosphorus content of the mixer iron, showing no appreciable retardation with phosphorus up to, roughly, 1 per cent.; whereas with phosphorus as high as 1·8 per cent. the duration of the heat is increased by about 8 per cent., the production per day being decreased in the same proportion.

The oxidation of the silicon, manganese, and phosphorus by the added ore proceeds very rapidly, the temperature being low, and, provided sufficient quantities of lime are employed, is completed with the melting down of the furnace contents. The oxidation of the carbon by the ore is dependent on (1) the concentration of the carbon; (2) the temperature; and (3) the heat supply.

A metal bath containing less than 1·4 per cent. carbon is much more rapidly oxidised by ore than one in which the carbon content is higher; and therefore the reduction of the carbon of the mixer iron to about 1 per cent. by the steel remaining in the furnace effects a considerable saving in time. Since the higher the temperature the more rapid the oxidation, the process is considerably favoured by the high heat reserve of the Talbot furnace at the commencement of the charge. The heat supply plays an important rôle in the decarburisation of the pig iron, since both the decomposition of the iron carbide (which in white pig iron contains the whole of the carbon) and the oxidation of the carbon liberated are only effected with a considerable absorption of heat. The quantity of heat necessary for decomposing the iron carbide is, according to Campbell, 705 calories per kilogramme of carbon. The oxidation of carbon by ore into carbon monoxide, according to equation

$$Fe_3O_4 + 4C = 3Fe + 4CO,$$

is strongly endothermic. Moreover, most of the heat generated outside the bath by the practically instantaneous combustion is lost for the process, so that the bath cools in spite of the simultaneous exothermic reactions of other admixtures.

The Wellman Furnace.—In the Wellman furnace the necessary cold charge of scrap, ore, and lime is introduced. Two ladles of mixer iron are added, the process then proceeding in the normal manner, similarly to that in the ordinary

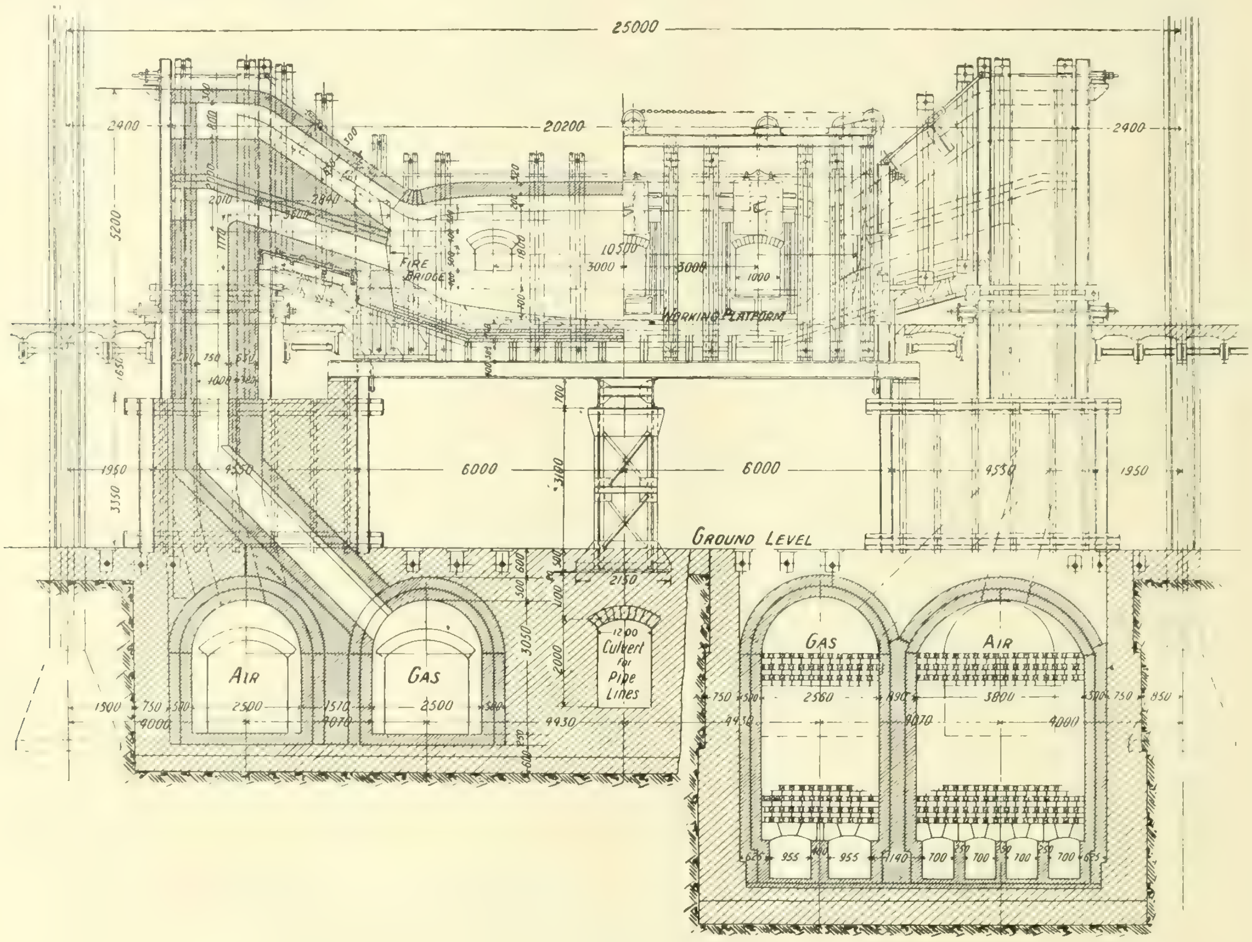


FIG. 6.—LONGITUDINAL SECTIONAL ELEVATION OF A 50 TO 60 TON OPEN-HEARTH FURNACE AT WITKOWITZ IRONWORKS.

* Paper read before the Iron and Steel Institute, May, 1914.

fixed open-hearth furnace. Just prior to tapping the finished charge, the slag is poured off, in this instance, to the side of the working platform, into slag wagons standing ready, the remainder of the slag running, with the finished steel, into the ladle. Recarburisation takes place by adding liquid ferro-manganese in the ladle. As the result of experiments undertaken, we have found the tilting Wellman furnace to work satisfactorily with an addition of scrap of from 10 to 15 per cent.

Fixed Open-hearth Furnaces.—As stated above, the three new 50-ton to 60-ton open-hearth furnaces at Witkowitz are intended (1) for working up the scrap produced in the rolling-mill; (2) for the manufacture of the special qualities of steel necessary. In normal working, these furnaces show therefore no departures from furnaces worked elsewhere on the scrap pig-iron process. The finished steel from all furnaces is recarburised by liquid ferro-manganese, the necessary additions being made while the steel is in the ladle. The steel is poured off into ingot moulds generally holding 4 tons, these moulds being placed in pairs on casting wagons, which, on the completion of casting, are conveyed on narrow gauge tracks to the reheating furnaces.

Since a succession of individual heats in open-hearth furnaces is never attainable in regular intervals, and as also the charge of 60 tons and over supplies, at one time, a large number of ingots which cannot be worked up at once by the rolling-mill, it was necessary to provide soaking pits forming the connecting link between the steelworks on the one hand and the cogging-mill on the other.

As a result of experiments, covering a working period of nearly 12 months, we were able to prove conclusively that it was possible in each of the three systems of furnace to produce a perfectly similar steel, both as regards physical and chemical properties; and further, that after some practice on the part of the furnace staff, there were no difficulties worth mentioning in producing in the fixed furnace, the tilting Wellman furnace, or the Talbot furnace, any kind of steel of unimpeachable quality, from the mildest up to the hardest.

The original fear which we entertained of not being able to produce in (for instance) the Talbot furnace, billets, mild and hard sheets, rails, &c., in a relatively rapid succession of the casts, has proved to be unfounded in every respect. On the other hand, we were able not only to manufacture the above-mentioned qualities of steel with perfect certainty, but also to produce material for weldless tubes, both of hard and soft quality—a product the manufacture of which is attended with great difficulties. Table III. gives the analyses of a series of steels manufactured in the various furnaces.

TABLE III.

Quality.	Carbon per cent.	Man-ganese per cent.	Silicon per cent.	Phos-phorus per cent.	Sulphur per cent.
Gas piping	0·09	0·43	—	0·03	0·025
Bore pipe	0·10	0·40	—	0·02	0·018
Seamless tube, mild......	0·14	0·50	—	0·02	0·017
Steel for fittings	0·11	0·51	—	0·03	0·021
Girders	0·12	0·54	-	0·03	0·029
Ship plates, C=0·14 to 0·15 per cent.	0·14	0·49	—	0·03	0·023
Ship plates, C=0·18 to 0·24 per cent.	0·19	0·49	—	0·03	0·027
Lightning arrester rods....	0·20	0·52	—	0·04	0·022
Material of 45 to 55 kilogs tensile (per mm_2) and 25 to 20 per cent. elongation	0·25	0·50	—	0·04	0·029
Material of 50 to 60 kilogs tensile (per mm^2) and about 15 to 20 per cent. elongation	0·29	0·57	—	0·04	0·021
Spring steel	0·31	0·80	0·24	0·04	0·024
Rails for Austrian State Railways..............	0·48	0·87	0·12	0·04	0·030

With a view to determining whether, as regards the production of pig iron for the new steelworks, we could work within fairly wide limits, we have produced pig irons of the most diverse composition in varying working periods, charging the different steel furnaces with such products. From the analyses to hand, we find that, especially in regard to the phosphorus content, we have worked within fairly wide limits and used pig iron containing approximately ½, ¾, 1, 1½, and 1¾ per cent. of phosphorus. With reference to the manganese content also, we have worked within fairly wide limits of from 1 per cent. to nearly 3 per cent.

We were able to obtain, in each of the three types of furnace, and with all these sorts of pig iron, steel of perfectly satisfactory quality, nor did we find appreciable differences in the quality of the resultant products when using a particular system. Only in regard to the quantity produced did the types of furnace vary from one another, namely, when the phosphorus content considerably exceeded 1 per cent.; and it was found that using a pig iron containing 1¾ per cent. of phosphorus, the production in the Talbot furnace decreased by, roughly, 8 per cent., and in the Wellman and the fixed furnaces by about 12 per cent., as compared with the pig iron containing 1 per cent. of phosphorus. It should, of course, be taken into account that the value of the slag produced increases owing to the increase of the phosphoric acid content; the gain on the slags is therefore correspondingly greater, and it only needs a simple calculation to ascertain how far the decline in output is equalised by the cheapening in the costs of production owing to the enhanced recovery of slag.

As the result of a fairly extensive series of experiments, we arrived at the conclusion that the Talbot furnace works the most favourably where it has to work up as little scrap as possible. A scrap addition of up to 5 per cent. does not influence the output. When this percentage is largely exceeded, the cooling off of the bath is very considerable, resulting in an appreciable extension of the period of the heat and the decline in output thereby caused.

In the case of the Wellman furnace, we were able to ascertain on the basis of the figures for the output obtained during the experimental period, that this furnace works advantageously with a scrap addition of 10 to 15 per cent.

The fixed furnaces work most satisfactorily with a scrap addition of 20 per cent. The yield is influenced by increasing the phosphoric content to 1¾ per cent., the result being, as already stated, a 12 per cent. drop in the output. Experiments to try working in the fixed open-hearth furnaces with mixer iron alone, or with but a few percentages of scrap, had to be given up after a few days, since the increased quantities of slag resulting caused difficulties in working, and appeared to exclude the possibility of permanent work on this basis.

TABLE IV.

Material per Ton of Steel.	Talbot Furnace.		Wellman Furnace.		O.H. Furnace.	
	1·1 per cent. P.	1·7 per cent. P.	1·1 per cent. P.	1·7 per cent. P.	1·1 per cent. P.	1·7 per cent. P.
Charge:	Kilogs.	Kilogs.	Kilogs.	Kilogs.	Kilogs.	Kilogs.
Pig iron (and mixer iron)	890	878	845	837	745	738
Scrap	67	66	115	114	246	244
Ferro-manganese and FeSi	6	6	7	7	7	7
Oxides:						
Gellivara ore	133	160	137	165	123	147
Mill cinder, &c.	37	44	34	41	23	27
Lime	90	108	93	116	91	109
Refractory Material:						
Dinas and refractory bricks	17	18	30	34	37	42
Magnesite and dolomite	15	16	17	19	20	22
Chrome ore	0·5	0·5	0·5	0·5	1	1
Fuel:						
Coal for furnaces	206	221	230	260	272	307
Coal for mixer	52	52	47	47	35	35
Coal for steam	18	19	20	22	22	24
Current, units	7·8	8·4	7·8	8·8	7·8	8·8
Kilos of slag	155	187	200	250	175	210
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
P_2O_5 in the slag	15·1	19·1	10·9	13·2	11·2	14·2
Yield	103·8	105·2	103·4	104·4	100·2	101·1
Oxides to pig iron	19·1	23·2	20·2	24·6	19·6	23·6
Scrap to charge	7·0	7·0	12·0	12·0	25·0	25·0

For the purpose of judging of the average costs of production attainable in the three types of furnace, the following points should be considered: (1) The ratio of initial costs of the various types of furnace selected, excluding the amount

of the building costs which must be expended on a steelworks plant without any regard to the choice of furnace, is dependent on local conditions and the magnitude of the total output. (2) Fuel expenditure. (3) Expenditure on fluxes, both acid (ore, cinder) and basic (lime). (4) The durability of the furnaces, and the expenditure on refractory material and wages for repairs, which are dependent on the life of the furnace. (5) Remaining expenditure, such as salaries, wages, water, and electric current supply. (6) Gain resulting from the utilisation of by-products, mainly slag.

A particular objection raised to tilting furnaces is their undoubtedly high cost of installation. The data to be found in the literature as regards the capital costs of furnaces of this type are not easily comparable with one another and with the cost-data for other systems of furnace. The reason for this is simply that the constructional costs depend, not only on whether the dimensions of the individual parts of the furnaces in question are to be liberal or otherwise, but also on the conditions of the country in which the building is

(which are less dependent on the selection of the type of furnace), have not been taken into account in the figures.

Table IV., containing the working results for the three systems of furnace, using pig iron containing 1·1 per cent. and 1·7 per cent. of phosphorus, shows the Talbot furnace to come out most satisfactorily as regards expenditure of fuel, on refractory material, on lime, and also on oxides (referred to pig iron), while in nearly all respects the Wellman furnace comes after the Talbot, the fixed furnaces coming last. The yield of iron from the added oxides is as follows:—

	Per Cent.
Talbot furnace	86
Wellman furnace	80
Open-hearth furnace	78

With reference to the slag, for obvious reasons the quantity is lowest in the case of the Talbot furnace and highest in the Wellman furnace, while in the case of the stationary open-hearth furnaces the quantity lies between that for the other two owing to the larger proportions of scrap

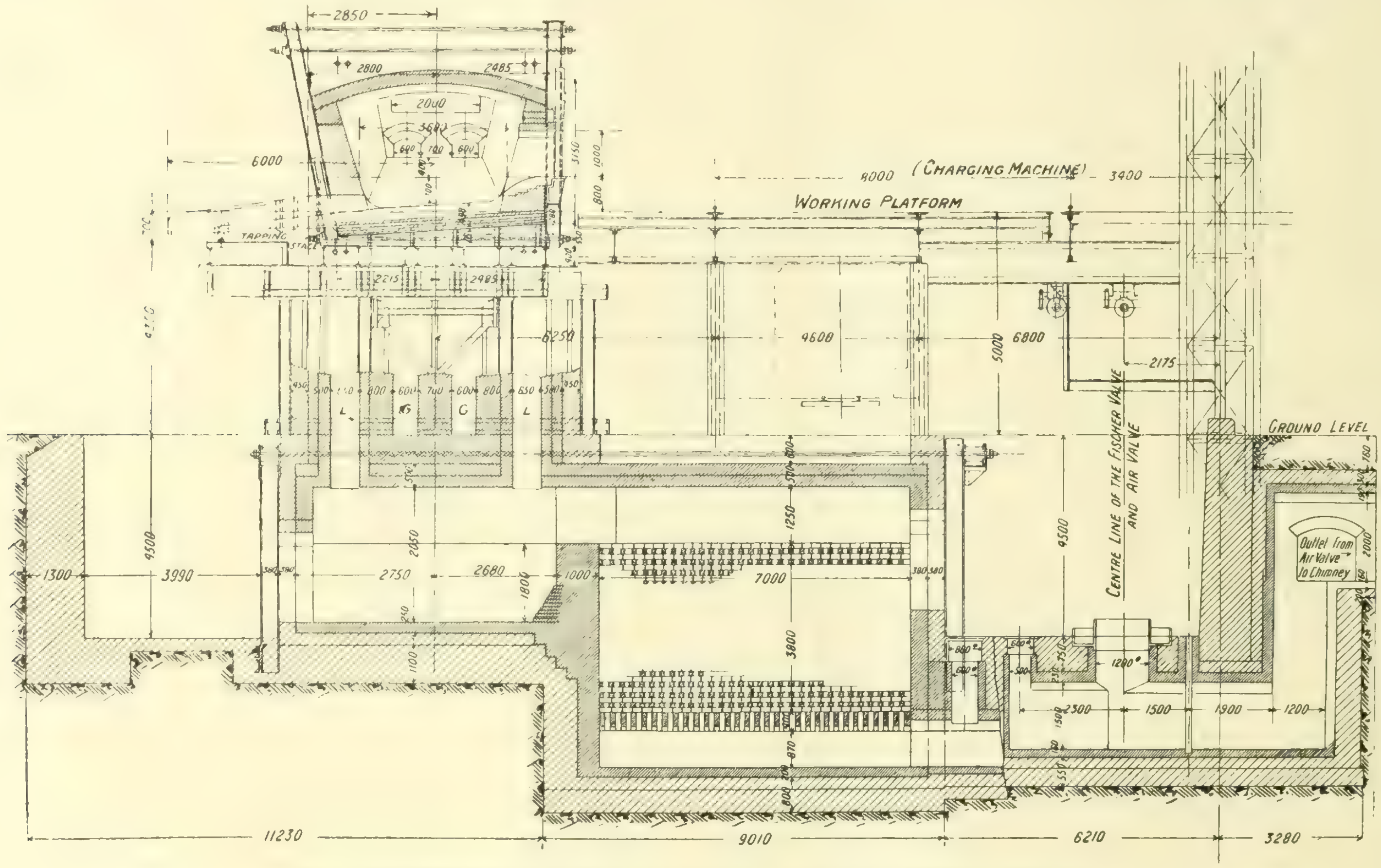


Fig. 7.—Cross section of a 50 to 60 ton Open-hearth Furnace at Witkowitz Ironworks.

carried out. Neither wages nor costs of material are, even approximately, alike in the steel-producing countries; in addition, differences in Customs charges, taxation, &c., affect the total constructional charges considerably.

A perfectly satisfactory comparison is therefore only possible where furnaces of different systems are erected alongside under the same general and special conditions of construction, such as is the case with us at Witkowitz. For reasons which will at once be apparent, I therefore hesitate to say anything about the definite amount for building, which is only of subordinate interest; I will restrict myself rather to giving relative values, which, however, are based on perfectly reliable statistics. According to these, the costs of construction of the Talbot furnace to those of the Wellman furnace and to a fixed open-hearth furnace, are in the ratio of 1659 : 1259 : 1000.

If, however—and this is probably the most important consideration—the cost price per ton produced daily is compared, we get a reversal of the above order, the ratio between Talbot, Wellman, and fixed furnaces being as 882 : 1070 : 1000.

In comparing the above values, it should be noted that they include not only the costs for the furnaces with fittings complete, but also the share of space allotted to each individual furnace in the furnace and casting houses. The charges for travelling cranes, charging machines, tracks, &c.

employed. In confirmation of this, we may say that our experiments show that the phosphoric acid content in the Talbot furnace is highest, whereas statements to the contrary in this connection have been made in various publications. The total quantity of phosphoric acid increases almost proportionally to the total phosphorus content of the charge, and decreases with the quantity of slag per ton of steel produced. Table V. contains typical analyses of Talbot slag.

Table V.

	Using Pig Iron containing	
	1·1 per cent. Phosphorus.	1·7 per cent. Phosphorus.
	Per cent.	Per cent.
SiO_2	9·43	9·24
FeO	8·63	8·10
Fe_2O_3	6·56	2·15
Al_2O_3	4·02	2·08
MnO	7·33	4·37
CaO	41·97	50·61
MgO	5·87	3·58
S	0·38	0·28
Total P_2O_5	14·70	19·02

The final composition of the slag depends, of course, to a great extent also on the choice of the ore used for oxidation, the fewer impurities the ore contains (in particular, the fewer silicates it introduces into the slag bath), the more concentrated the form in which the phosphoric acid will generally appear; since under otherwise equal conditions the Talbot process requires the smallest quantity of oxide additions, it at once follows that the Talbot furnace slag has the greatest concentration of phosphoric acid, this fact being shown satisfactorily in the tables.

Turning now to the life of the furnaces, we have been able to confirm the following data relative to this question:

Talbot Furnace.

	Charges.
With fresh lining, the "Friedrich" ends were changed after about	300
Further changing of ends after a further (approximately)	250
Fresh lining after a further	200
Consequently, we get	750

from one lining to the other with the same roof.

With one lining a quantity of (750 × 65·6 tons) = approximately 49,200 tons of steel was produced.

Wellman Furnace. This required, after re-lining and working about 220 charges, new ends and repairs (walls and piers); and after about 220 further charges a new lining; consequently a total of 440 charges (approximately) was obtained with one lining and with the same furnace-roof. With one lining (440 × 62·8 tons) = approximately 27,600 tons of steel were produced.

Open-hearth Furnace.—This required, after re-lining and 250 charges, fresh ends and repairs (walls and piers); after a further 250 charges, fresh lining; consequently about 500 charges were obtained with one lining with the same roof. With one lining (500 × 55·7 tons) = approximately 27,800 tons of steel were produced.

The above figures show the life of the lining of the Talbot furnace to be appreciably longer than that of the other types. The main reason for this is that the Talbot furnace works very much more rapidly and the reactions are more energetic, proceeding downwards from the large bath area. In the Wellman and open-hearth furnaces, on the other hand, lime and oxides react upwards from the bottom, causing a frothing of the metal and slag bath lasting some hours, so that the slag rises considerably, strongly attacking the walls, pillars, fire-bridges, and ports.

A remarkable fact is the considerably greater life of the masonry of the ladles used with the Talbot furnace as compared with those used with other types. This is attributable to the entire absence of slag in the ladle of the Talbot furnace, whereas in the case of the Wellman furnace, and particularly with the fixed furnaces, the more or less considerable covering of slag above the metal bath is the principal reason for the rapid deterioration of the bricks of the ladle. The remaining items in the cost of production have, as the experiments covering a period of one year show, been found to be lowest in the Talbot furnace.

TABLE VI.—*Cost in Shillings.*

		Basic Process (according to Schock's Table)			Scrap and Pig Process (according to Schock's Table)			Pig and Ore Process (according to Schock's Table)			Talbot Process (New Steelworks, Witkowitz)			Wellman Process (New Steelworks, Witkowitz)			Open-Hearth Process (New Steelworks, Witkowitz)			[illegible] (Old Open-Hearth Works, [illegible])		
Phosphorus in pig iron (approximate)		1·8 per Cent.			1·8 per Cent.			1·8 per Cent.			1·7 per Cent.			1·7 per Cent.			1·7 per Cent.			[illegible] per Cent.		
Yield		89·5 ,,			96·0 ,,			107·0 ,,			105·2 ,,			104·4 ,,			101·1 ,,			[illegible]		
Loss of balance		0·6 ,,			1·6 ,,			0·8 ,,												3·1 ,,		
Daily production		1063 tons			159 tons			1484 tons			295 tons			175 tons			300 tons			[illegible] tons		
	Cost per Ton Shillings	Weight per Ton of Yield	Shillings per Ton of Yield: Item	Total	Weight per Ton of Yield	Shillings per Ton of Yield: Item	Total	Weight per Ton of Yield	Shillings per Ton of Yield: Item	Total	Weight per Ton of Yield	Shillings per Ton of Yield: Item	Total	Weight per Ton of Yield	Shillings per Ton of Yield: Item	Total	Weight per Ton of Yield	Shillings per Ton of Yield: Item	Total	Weight per Ton of Yield	Shillings per Ton of Yield: Item	Total
		Kilog.			Kilog.			Kilog.			Mixer Costs.			Mixer Costs.			Mixer Costs.					
Charge: Basic pig iron	11·0	1090·0	17·96		269	11·44		813·0	35·77		878	3·80		837	[illegible]		[illegible]	2·57		1068·1	47·0	
Charge: Scrap	56·0	20·0	1·12		767	42·95		115·6	6·47		66	38·63		114	36·82		244	32·47		66·1	[illegible]	
Charge: Ferro-manganese	200·0	6·5	1·30		9	1·80		6·0	1·29		6	3·70		[illegible]	[illegible]		7	13·66		9·0		
Charge: Ferro-silicon												1·20			1·40			1·10		0·7	[illegible]	
Charge: Spiegeleisen	...																			1·3		
				50·38			56·19			43·44			47·33			48·05			50·10			52·34
		1116·5			1036			931·6			950			958			989			[illegible]		
Cost per ton of charge			(45·12)			(54·23)			(46·47)		With Mixer	(49·82)		With Mixer	50·15		With Mixer	[illegible]			(46·11)	
,, ,, scrap and pig			(44·21)			(52·96)			(45·50)		Without Mixer	(44·84)		Without Mixer	(45·42)		Without Mixer	[illegible]			(44·60)	
Oxides: Swedish ore	28·0							150	4·20		160	4·48		165	4·62		117	[illegible]		27·2	0·76	
Oxides: 50 per cent. manganese ore	12·0							18	0·75													
Oxides: Cinder (own)	15·0				35	0·525		20	0·30		41	0·66		41	0·61		27	0·41				
Oxides: ,, (bought, slag)	17·0						0·525	87	1·48	6·73			5·14			5·23			[illegible]			0·76
Total ore and metal				50·38			56·715			50·17			52·47			53·28			54·63			[illegible]
Lime	12·0	150	1·80		60	0·72		125	1·50		108	1·30		116	1·39		[illegible]	1·31		78	[illegible]	
Fluorspar	25·0				1	0·025		1	0·025													[illegible]
				1·80			0·745			1·525			1·30			1·39			1·31		—	
Fuel: Cost of gasifying												0·98			1·15			1·37				
Fuel: Coal	19·0				220	4·13		220	4·18		221	4·20		260	4·94		[illegible]	5·84		267	[illegible]	
Fuel: Coke, graphite, wood, &c.			0·24			0·125			0·10													
				0·24			4·305			4·28			5·18			6·09			7·21			5·07
Refractory Material: Chrome ore	65·0				1	0·065		1	0·065			1·40			2·45			2·52			[illegible]	
Refractory Material: Refractory material for furnace						0·90			1·60													
Refractory Material: ,, ,, working			0·35			0·20			0·35													
Refractory Material: Dolomite, tar, including wages			0·70			0·60			0·60													
				1·05			1·765			2·615			1·40			2·45			2·52			[illegible]
Steam, gas, electricity			0·50			0·17			0·20			1·71			1·71			1·62			[illegible]	
Tools, stores, and spare parts			0·40			0·50			0·50													
Other operations, wages, material			1·00			1·00			1·00													
Direct wages, salaries, bonus			0·95			2·00			1·50			2·28			2·40			[illegible]			[illegible]	
Ingot moulds			0·50			0·50			0·50			0·50			0·50			[illegible]			[illegible]	
General, royalty, depreciation, &c.				3·35			4·17			3·70			4·49			4·61			[illegible]			8·25
Gross cost of production				56·82			67·70			[illegible]			[illegible]			[illegible]			[illegible]			[illegible]
	20·0	230 (17 per cent.)	4·60																			
Less—Value of slags	3·0				110	0·32																
	23·50							110 (18·5 per cent.)	3·10													
	2·60							165 (6·9 per cent.)	0·41		187 (19 per cent.)	5·15		250 (15 per cent.)	[illegible]		210 (11 per cent.)	[illegible]			[illegible]	
Steam and waste heat utilised									0·48													
			—	4·60			0·42		—	4·29		—	5·15		—	[illegible]			3·20			[illegible]
Net cost of production				52·22			67·28			58·00			[illegible]			[illegible]			[illegible]			[illegible]
Cost of conversion (referred to 1 ton of scrap and pig)				8·01		Average 54·18 / 8·83 Shillings	11·32			12·50			[illegible]			[illegible]			[illegible]			[illegible]
Comparative cost of production				100		104	129			111			[illegible]			[illegible]			125			[illegible]

Another fact contributing to the longer life is that the Talbot furnace always remains at least partially filled with liquid material, and the masonry is not exposed to such considerable temperature fluctuations as in the case of furnaces which are emptied completely after each charge and afterwards freshly charged. As regards the gain from the by-products, this results from the utilisation of the slag (containing phosphoric acid) which is produced. In this case also the result is most favourable for the Talbot furnace, as although the quantity of slag is less than with the other furnaces, the phosphoric acid concentration is comparatively greater and the sale price for the slag correspondingly higher.

Since the general level of the manufacturing costs at each individual works is influenced by the cost of production of the pig iron and the market price of scrap, and, further, depends on the price and quality of the coal employed and of

the subsidiary material, wages, &c., I do not think it desirable to express in money the figures which apply to our case, and will restrict myself rather to giving the comparative figures obtained as a result of a long period of experiment. If the total costs of production of steel as produced by the Talbot process be taken as equal to 100, the costs of production with the Wellman furnace rise to 105, and in fixed open-hearth furnaces to 107, including charges on account of working the mixer.

In order also to render possible a comparison with the conditions prevailing in West Germany, I have recalculated our effective working results, using the tables representing average values for the West German district, as given in the paper by Schock already mentioned, and taking as the basis of our working calculation the unit prices of material given in that paper. All those values, which refer to quantities, are the result of an exact determination over a long working period. The amounts for wages and miscellaneous expenses have been converted into marks, according to the actual attainable conditions. If, now, the costs of production obtained in this manner are compared with each other, and the costs of production for basic Bessemer steel are taken as 100, we obtain values which are again comparable, and working out at: For the scrap pig-iron process, according to Schock, 129; for the pig-iron ore process, 111 (which may be taken as being too favourable); for the Talbot process, 114; for the Wellman furnace, 123; for the fixed open-hearth furnace, 128; and for the duplex process, 133.

If in this series of values the cost of production by the Talbot process be again taken as equal to 100, the costs for the Wellman furnace come out at 108, and for the fixed open-hearth furnace at 112, in comparison with the values 100 : 105 : 107 as based on the Witkowitz conditions. The reason for this discrepancy is to be sought for simply in the difference in the manner of utilising the raw materials. The detailed calculations are given in Table VI.

With a view to clearing up one of the most important points, namely, the yield attained in the various systems of furnace, we have carried out experiments over a period of six weeks, during which a large staff of engineers and others carried out a thorough check day and night on the materials conveyed to the furnaces, and on the products obtained. Care was taken to see that any waste iron in the castings and in the slags was entered to the credit of the furnace whence it originated. The result of these experiments went to show that the yield of all three types of furnace, using the same raw materials and working under approximately the same ratio of pig iron : mixer iron : scrap respectively, was the same. We do not see how any appreciable difference could result, as the ore added is actually dependent on the quantity of impurities which have to be oxidised. Certain discrepancies in the yield occurred only where the ratio between mixer iron and scrap was varied. These experiments were carried out with pig irons containing both 1·1 per cent. and 1·7 per cent. of phosphorus.

Conclusion.—In finally summing up the results of our various experiments, I wish first of all to emphasize the fact that any conclusions drawn from them apply strictly only to our Witkowitz conditions, and assume an average daily production of from 800 to 1,000 tons of steel; and that mathematical divergences from our conclusions may result on repeating these experiments in a different locality and under different conditions. Apart from this, however, we may arrive at a number of conclusions which may claim to be generally applicable.

Taking for granted the above remarks, we have been able to find:—

1. By using a mixer (capable of being heated) and carrying out but a small amount of refining in the same, the production of the steel furnaces supplied by it can be increased by about 30 per cent.

2. The quality of steel produced is, both physically and chemically, independent of the choice of furnace employed.

3. The yield is influenced by (*a*) the pig iron employed and (*b*) the ratio of scrap to mixer iron and pig iron respectively; and such yield is practically the same whenever the same conditions are observed in furnaces of different types.

4. The Talbot furnace is the type most adaptable to the working up of pig iron of varying composition, and to changes, within fairly wide limits, in the amount of scrap added.

5. In the Talbot furnace pig iron of the lowest to the highest phosphorus content can be worked up without deteriorating the quality of the steel, the decline in output with pig iron rich in phosphorus being smaller than in the case of other types of furnace.

6. Although the actual first cost of the Talbot furnace is appreciably higher than that of a tilting furnace of small capacity, or of a fixed open-hearth furnace, these costs, calculated per ton produced daily, work out most favourably for the Talbot furnace.

7. The yield of metallic iron from the oxide additions (ore and cinder) is higher in the Talbot furnace than in other types.

8. The slag produced in the Talbot furnace is (owing to the concentration of the phosphoric acid when using pig iron of high phosphorus content) more valuable than in other types of furnace; and therefore the gain arising from the sale of the slag is greater.

9. The fuel expenditure is lower in the Talbot furnace than in the other furnaces.

10. The life of the refractory lining is longer in the Talbot furnace than in other systems, and thus both the charges for repairs and the total consumption of refractory material for working come out most favourably in the case of the Talbot furnace.

11. The working of the furnace is, in the case of the Talbot furnace, most simple and convenient, especially on account of the easy removal of the slag by tipping the furnace.

12. The work of the furnace staff is less trying with the Talbot furnace than with the remaining types; and the number of persons necessary for carrying out the process is, relatively, the smallest.

From what has been said, it may safely be maintained that, for open-hearth steelworks producing medium and large quantities, the Talbot furnace is superior to all other types, so that it may reasonably be described as the open-hearth furnace of the future.

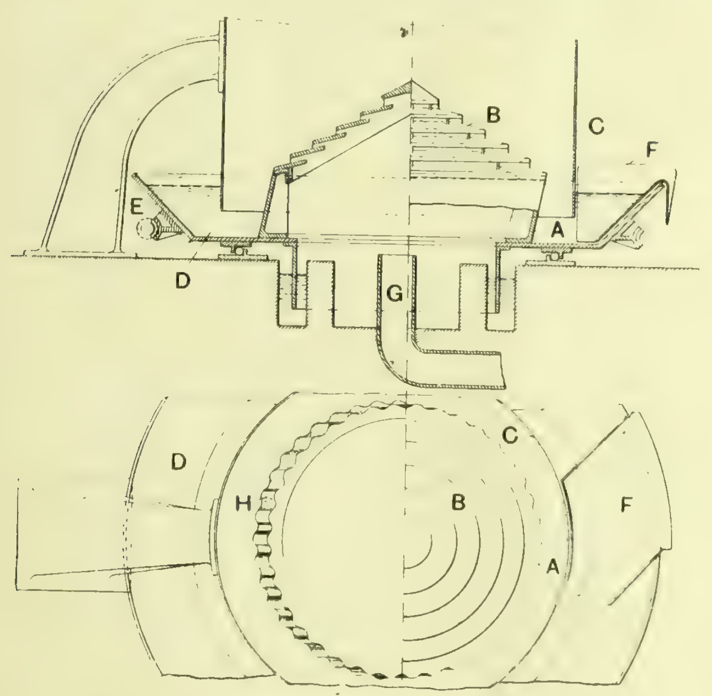
ELECTRIC STEERING GEAR FOR VESSELS.

AT a meeting of the American Institute of Electrical Engineers, held on May 19th, a paper was presented by H. L. Hibbard, on "Electricity, the Future Power for Steering Vessels." The author first dealt with steam steering gear, and drew attention to its disadvantages. Turning to the electric drive, he claimed that the following results could be accomplished with this method: (1) Reduction of weight and space of driving mechanism; (2) reduction of heat in steering-gear room; (3) elimination of accidents with steam pipes; (4) reduction of vibration and noise; (5) increase in efficiency; (6) simplification of control and ease of operation; (7) increase in rapidity and accuracy of rudder movement. He outlined the electric steering gears heretofore used, one of the first successful ones being the Pfatischer system used on a number of naval and merchant vessels. This system employed a shunt motor for operating the rudder and it was controlled with varying voltage supplied by a motor-generator set. The field of the generator was controlled from the steering wheel on the Wheatstone-bridge principle, one arm of the bridge being a rheostat located at the steering wheel and another located at the rudder crosshead. The unbalancing of the bridge by the movement of the wheel gave current to the generator field and consequently to the rudder motor. The movement of the rudder crosshead cut off current from the generator field and the motor was stopped. This constituted an electric follow-up control. Objections to this system were the weight and cost of the motor-generator set, and the fact that it was always using power. The available power decreased as the rudder approached the balanced position, yet this was the point where maximum torque was frequently desired. Other systems had been tried in the U.S. Navy without much satisfaction. Two Argentine battle-ships just being completed had a system combining rheostatic and field control, which the author described. The paper was mainly devoted to a description of the system used on the U.S. battle-ships

"Texas" and "New York." This system used power directly from the dynamo mains. The motor had a disc brake and the main automatic controller and resistance were installed near it, with a limiting switch. Master controllers were furnished on the bridge, in the conning tower, in the central-control station, and in the steering gear room. The reversing switch was operated by a lever which returned to its middle position when released. A small movement of this lever caused the motor to start and run at low speed, and further movements caused the movement to accelerate more rapidly to full speed. There was no follow-up control. The rudder kept moving as long as the operating lever was in the running position and stopped when it was returned to the central point. A control panel contained the automatic contactors for reversal, acceleration, and dynamic brake. The calculation of the necessary horse-power was given and tests on the complete equipment showed this to agree very well with actual requirements. The trial tests had proved the gears to be satisfactory. Graphic charts were given showing the current requirements, which involved peaks of 1,600 amperes. There was, the author claimed, a saving in weight, space and efficiency by the use of this system and an ease and accuracy of control. The rudder could be operated through 40° in 16·5 seconds. A motor of slightly over 100 h.p. would be sufficient for the "Texas."

ROTARY GRATE FOR GAS PRODUCERS.

An arrangement of rotary grate for gas producers, the invention of Mr. J. A. Weil, Bowesfield Lane, Stockton-on-Tees, is shown in the accompanying cuts. The cylindrical part of the grate is an oblique cylinder, that is to say, a cylinder having its axis inclined to its base. By this construction there is secured a crushing action on the clinker or fuel between the periphery of the cylinder and the casing of the producer, accompanied by a stirring effect on the fuel and a working of the ash down into the water trough. These



Rotary Grate for Gas Producers.

actions are enhanced by corrugating the periphery of the cylinder, whereby also the ash is prevented from being merely moved in a circle. Referring to the illustrations, the grate A has the conical grate B mounted on it, the base of the grate A being concentric with the casing C of the producer. The grate is fixed to the water trough D mounted to rotate on a ball bearing and driven by a worm gear E. The ashes are removed from this trough by an inclined fixed scraper F. G is the usual blast pipe. The periphery of the cylindrical portion of the grate is corrugated as at H.

BY-PRODUCTS OF STEEL MANUFACTURE.*

BY ADOLPHE GREINER, D.SC.

(Concluded from page 511.)

Blastfurnaces.

In concluding his own excellent address, my esteemed predecessor, Mr. Arthur Cooper, recalled the remark made by our deceased friend, Mr. E. P. Martin, who, in his address in 1897, said: "It would almost appear as if pig-iron would soon become a by-product. The chief work of the ironmaster of the future will be giving light and power to the country." To this witty prognostication Mr. Cooper added the following reflection: "It is clear that Mr. Martin in 1897 regarded this subject as a most important one, but it is far more important to us to-day, having regard to the great increase in the cost of coal which has already taken place, and the certainty of a still further increase in the near future." Let me add to that, "and to the strong depression actually existing in the price of pig-iron itself." I shall indeed be telling blastfurnace managers nothing new when I tell them that on the Continent, as in England, the price of pig iron has fallen during a twelvemonth by 20 to 25 per cent., and more than one furnace has to depend upon the resources arising from the employment or the sale of its by-products.

1. *Blastfurnace Gases.*—For a long time past blastfurnaces have ceased to be "beacons of industry." The tops have not, however, been completely closed up for more than about 30 years, a good number of engineers claiming that it was necessary to visually inspect the uniform descent of the charge. But, even with open tops, a portion of the gases from the throat of the furnace had already served to heat the hot-blast stoves, which were formerly composed of cast-iron tubes of varying shapes. A considerable improvement in their method of working was introduced by the employment of gas subjected to preliminary cleaning in order to remove the dust which, in the form of deposits, fouled the chequer-work of the stoves and choked up the channels.

To give an idea of the improvement resulting from the use of washed gases, I may instance the fact that the stoves of one of the large blastfurnaces of the John Cockerill Company became choked up generally after four or five months' working, and required complete cleaning out. After running for two years with gas, cleaned to the extent of 0·5 gramme per cubic metre, the same stoves have required no cleaning whatever, and may run two or three years longer without stoppage.

Numerous appliances have been invented for the purification of blastfurnace gases, which sometimes contain up to 10 grammes of dust per cubic metre. Generally speaking, capacious reservoirs with culverts of large diameter suffice to effect preliminary purification. By reducing the rate of flow of the gases, over 50 per cent. of the coarser dust becomes deposited by this simple static process. When, however, it is desired to reduce the percentage to 0·1 gramme of dust, or even lower, dynamic processes have to be employed, that is to say, the gases have to be centrifugalised with water sprays, and for this purpose there is no lack of appliances. Two types are very commonly employed on the Continent; one is composed of vertical washers with wooden baffles and a water-sprayed fan—the Zschocke system, the other consisting of a washer with a highly ingenious water spray and disintegrator, a sort of turbine in which the gas circulates in the opposite direction to a current of water—the Theisen system—that seems to solve the problem better still. In either type of appliance the dust is entangled in the form of mud, in the troughs where it becomes deposited; the gases emerging almost at the temperature of the injected water, and saturated with moisture.

Works that do not possess a good supply of water employ, in preference, a form of dry-cleaning such as the Halberger-Beth system, in which the cooled gases are filtered through bags of specially made canvas, through which they are drawn by an exhaust fan. This type of cleaner requires less motive power and carries purification to the greatest possible extent, as the gas practically contains no dust. The operation is, however, somewhat delicate; the plant occupies more space,

* Abstract of presidential address delivered to the Iron and Steel Institute, May 7th, 1914.

and its installation is more expensive. For the purpose of comparison the following figures may be given; they are not to be considered, however, as determinative in the matter of the cost price per cubic metre of the gas:—

System.	Consumption of water per 1,000 cubic metres.	Power required per 1,000 cubic metres.	Degree of purification per cubic metre.
	Cubic metres.	Horse-power.	Gramme.
Zschocke	5	6	0·3 to 0·5
Theisen	3·5	4	0·08
Halberger-Beth	0·02	2	0·01

Some years ago doubts were raised as to the advantages of purifying gases prior to burning them under boilers, the opinion being held by some persons that the expense entailed by the cleaning was not counterbalanced by a superior yield in steam raising capacity. But, practically, the question has now been solved, and it may be said, speaking generally, that it is better, from every point of view, to discharge the dust, in the form of mud, into rivers and into the sea than to discharge it, in the form of smoke, into the atmosphere. When circumstances prevent this it is necessary to have recourse to settling troughs, which are less convenient. Formerly, when the gases underwent no cleaning it was possible to judge the working of the furnaces some distance away, by the more or less pronounced clouds of smoke emerging from the tall chimneys of the apparatus and the boiler stacks. At present the gases are hardly silhouetted against the sky, and this means of checking proceedings at a distance has been lost.

It is to William Whitwell that the honour is due of having recuperated heat in brick-lined regenerators, while since Cowper advantageously modified the interiors, the height of the stoves has steadily increased until they now attain 30 to 32 metres (98ft. to 106ft), while their efficiency increases. Anyhow, the heating of the blast is still an exceedingly expensive proceeding, and it may be permitted to hope that important improvements may yet be realised which will permit of the withdrawal of a smaller proportion of the blastfurnace gases for raising the temperature of the blast to 800° or 900° C.

The drying of the blast by the Gayley process does not furnish adequate results. It is necessary to seek to improve the combustion in the Cowper stoves by a more intimate admixture of gas and air, and better still, by heating the air required for its combustion by means of regenerators, as is now done in the case of reheating furnaces and of coke ovens.

The production of cheap oxygen by the fractional distillation of liquid air probably carries with it in reserve, pleasant surprises. The trials carried out in Belgium in enriching the oxygen of the blast have been very encouraging.

It is usually estimated that with the means employed one half of the gas emerging from the furnace tops is absorbed in the Cowper stoves, and that the remaining half is available for gas engines or boilers. We know, too, that given equal power, a gas engine consumes less than half the amount of gas consumed beneath the boiler to supply even the most perfect steam engine, while most of the metallurgical works in Europe have made the installation of gas engines the general practice. Such engines are now found in all countries. The number of gas engines at work of over 200 h.p. is estimated at over 900, representing an aggregate of at least 1,500,000 h.p., while to these figures must be added those in the United States of America. Belgium occupies a highly honourable place amongst the great industrial nations, with 94 gas engines developing a total of 128,000 h.p.

We have travelled far from the initial stages of 1895, when I brought before the Institute the preliminary results obtained at the Cockerill Works with the Delamarre-Debouteville engine, and when I had decided upon the use of uncleaned blastfurnace gases after trials of a small 8 h.p. motor, which I subsequently modified. I would, in this connection, pay to the memory of B. H. Thwaite the tribute he deserves for having made known the results of the earliest experiments carried out at the works of the Steel Company of Scotland, under the management of James Riley, and those of the experiments at Doncaster, and for pointing out the advantages conferred by the direct utilisation of blastfurnace gases for the production of electrical energy. The pioneer's untimely death prevented him from reaping the fruit of his investigations.

The first more definite results in this direction were furnished by Prof. Aimé Witz, who has recorded in the "Journal of the Institute" the results of the highly elaborate experiments carried out by himself and Prof. Hubert, in July, 1898, at Seraing. Within a few weeks there will be put into operation at those works the most powerful gas engine hitherto constructed. It will develop 8,000 h.p. What progress has been made, too, in engineering! Within 15 years we have witnessed the almost complete transformation of the means of producing motive power on a large scale. On the one hand, the gas engine has solved, practically, the rational utilisation of blastfurnace and coke-oven gases; on the other, the steam turbine extracts from the coal a far greater amount of energy than the piston engine ever rendered available.

Does the future hold, in further store for us, the promise of the gas turbine? Possibly so, although up to the present the ascertained results have not been very encouraging. In the meanwhile the central power stations of metallurgical works continue to develop. Many such stations possess from five to 10 gas-driven blowing engines, and 10 to 15 motor generator sets developing sometimes an aggregate of over 30,000 h.p. They are fed with coke-oven or blastfurnace gas —sometimes with both—after complete purification. Experience has shown that, after six months' running, the dust deposits, even in the most tortuous windings of the cylinders, are scarcely appreciable, provided the gas does not contain over 0·025 gramme per cubic metre. On the other hand, if the cooling water is not too hard, the cleaning of the deposit from the cylinder walls need only be effected every second or third month. Look, likewise, at the advantages that may be derived by the utilisation of the spent gases, on their leaving the engines; the 500 degrees of heat they carry off with them yield in appropriate boiler plants, an amount of steam which can be used in machines of different descriptions, or, better still, in turbines. Careful experiments have established that by these means 10 to 13 per cent. of the effective energy of the gas engine can be recovered.

(2) *Slags, Cement, Bricks, Ballast, and Agglomerates.*—The gases are not the only by-products of pig iron; there are also the slags, the annual production of which is estimated at close on 200,000,000 tons, which accumulated, in enormous tips, in the neighbourhood of works, encumber land, which often, in the course of years, acquires considerable value. The endeavour to turn them to profit is a problem deserving of the closest attention of metallurgists.

When the slags are acid they are made to serve for the manufacture of slag-wool, formerly employed as a heat-insulating packing, but since the bulk of the slags have become calcareous it has been in the direction of the manufacture of artificial cements that ingenuity has been brought to bear upon their employment. With this object they are granulated by cooling them, as they flow from the blastfurnace, either by water-spraying or by means of air-jets. By drying them, mixing them with 25 to 30 per cent. of hydraulic lime, and grinding them in various forms of mill, a fine powder, leaving not more than 12 per cent. of residue on a sieve having a mesh of 4,900 per square centimetre (12,500 per square inch), is obtained, which constitutes a cement of excellent quality, corresponding to the requirements of ordinary specifications, viz., a breaking strain of 10 kg. to 18 kg. per square centimetre after seven to 28 days (142lbs. to 263lbs. per square inch), and a crushing strength of 100 kg. to 180 kg. (1,422lbs. to 2,632lbs.) in the ordinary mortar.

When, however, it becomes a question of satisfactorily conforming to the new German specifications, which stipulate for a crushing strength of 250 kg. (3,554lbs.) after 28 days, it is better to manufacture slag cement by burning. For this purpose a mixture of 75 per cent. of granulated slag is fritted in the kilns usually employed in the Portland cement industry, with 25 per cent. of lime; by these means there are obtained nodules, or semi-fused agglomerates, possessing a special molecular texture and termed "clinker." A mixture of 70 per cent. of clinker and 30 per cent. of granulated slag, finely ground, yields a cement of superior quality,

known in Germany as "Eisen-Portland," and accepted during the last five years, under the same category as Portland cement, by public administrations and the International Sales Syndicates.

The cement industry has grown greatly of recent years; it is estimated that the annual European production of various slag cements reaches the figure of 1,000,000 tons, and this amount will not fail to increase. To this must be added the enormous output of the Steel Trust, whose cement works have just been considerably enlarged. The important development of the use of ferro-concrete further opens up to their use a promising future.

Side by side with cements there is being carried out, at many works, the manufacture of bricks. The granulated slag mixed with a small percentage of slaked lime is put under presses, and the bricks thus formed, and heated in autoclaves under steam at a pressure of one to eight atmospheres, acquire a remarkable degree of hardness. Their uniformity of shape and their pleasing appearance has created a demand for them for all kinds of masonry work, which they render drier and more impervious to moisture than ordinary brick.

Of late a good deal of slag, broken up, graded, and screened, has been used for the ballasting of railroads and for the construction of highways, where, either alone or in admixture with tar or with cement, it forms very firm surfaces. Whatever is done, however, it has to be remembered that all the applications devised for the utilisation of slags as saleable by-products are "up against" the enormous amount of their production, and they must continue to be, for a long time yet, the despair of the ironmaster.

Another by-product which possesses importance is that derived from the heavy dust recovered from the dust catchers, which has a composition closely approximating to the ores employed in the furnace burthen. The amount varies greatly, according to the nature of the ores used. In some works, for example, those which employ a large proportion of the Lorraine ores, it may be estimated at 6 to 10 per cent. of the charge. Experiments have everywhere been made to agglomerate it and use it, in this form, in the blastfurnace.

The cost of agglomeration varies from 1s. 8d. to 4s., according as to whether a binder is used, such as quicklime, calcium chloride, magnesia, &c., or whether it is nodulised by roasting. As the material, when nodulised, possesses the value of the natural ore, the saving is considerable.

STEELWORKS.

If the slag derived from the dephosphorising process in basic converters can be regarded as by-products, the value to be attached to this material is one of which Thomas and Gilchrist could hardly have even suspected the importance at the time of their memorable invention in 1875. In his paper read before the Institute in 1887, Gilchrist, who at that time estimated at 400,000 tons the total slags containing from 17 to 20 per cent. of phosphoric anhydride produced during the year preceding, pointed out that out of a total of 2,500,000 tons of phosphatic manures consumed in the five largest countries using them, the proportion of slag already being used was of favourable augury for the future. He was not far wrong, for, according to a proximate calculation, the production of basic slag in 1913 must have attained close on to 5,000,000 tons, worth nearly 200 millions of francs (£8,000,000), distributed as follows:—

Basic Slag Production in 1913.

	Tons.
Germany and Luxemburg	3,415,000
France	735,000
Belgium	500,000
Great Britain	325,000
Sweden, Russia, and Canada	80,000
Total	5,055,000

There are still, in a modern steel works, very many economies to be effected by the judicious application of the heat losses from the converter itself down to the smallest mill-reheating furnace. Gjers, by his invention of soaking pits, an invention which, for its simplicity, recalls the historical instance of Christopher Columbus and the egg, opened up a road upon which, it seems to me, we have since come to a standstill. Who can say that our engineers will not some day solve the problem of recovering the enormous heat losses in the flames of the converter? Theoretically, per ton of coal there are 180,000 calories available at the mouth of a basic converter, an amount which represents, on a daily production of 1,000 tons of steel, the very respectable total of 180,000,000 calories wasted into the atmosphere. This heat could be utilised beneath boilers, the steam from which could supply a turbo-blowing engine. A calculation will show that its complete recovery would yield 40 h.p.-hours per ton, which corresponds with 2,000 h.p. available permanently for a steel production of 1,000 tons per 20-hour day. That is, nearly the power of the blowing engine, and the refining of the pig iron could thus be effected without the expenditure of any further calorific energy.

Is the importance of the heat losses by radiation from the numerous reheating furnaces always borne in mind? Do we remember always that the temperature of the gases at the foot of the stack should never exceed 300° C., whereas they often attain to 600° and even higher? If this loss of calories is relatively small in good boiler plants and in well-regulated gas producers, where it can hardly exceed 25 per cent., what shall be said of the squandering of the calorific energy which takes place in the open-hearth furnace, and, above all, in the reheating furnaces?

Not more than 132,000 calories are needed to raise the temperature of a ton of steel from 0° C. to 1,200° C., the temperature of rolling. Now, a furnace charged with cold ingots requires, roughly speaking, 125 kg. (2½ cwts.) of coal to raise it to the temperature of rolling—that is to say, 875,000 calories; the loss, therefore, is 85 per cent.! And how many furnaces are there which are even more wasteful? Really, we metallurgists must sometimes feel absolutely ashamed to quote certain figures!

How many steam rolling-mill engines, and in particular of reversible mill engines, are there which are discharging into the atmosphere clouds of steam which could be used in low-pressure turbines of the Rateau type? A little reflection will show that the wastage of heat is still enormous, and that the last word has by no means been said in respect of the heat economies which might be effected in steelworks.

Side by side with these economies of to-morrow there are those which yield all the by-products I have already enumerated, and from which metallurgical works derive greater or less profit, according to the degree of perfection attained to by their coke ovens, the state of their blastfurnaces, and the use they make of their available gases.

If a metallurgical works produced, itself, in regenerative coke ovens, all the coke required for its blastfurnaces, if it manufactured bricks and cement from its slag, and found, in its steelworks, application for all the available gases, either in its open-hearth and its reheating furnaces, or in the production of motive power, it would effect, per ton of pig iron, profits which may, in detail, be shown as follows:—

		Yield s.	d.
Coke ovens per ton of coke.	Sulphate, tar, and benzols	3	9½
	200 cubic metres of gas at 0·12d.	2	0
Blastfurnaces per ton of pig iron	Cement, bricks, and slag	0	7½
	1,250 cubic metres of gas at 0·03d.	3	1½
	Recovery of dust	—	
	Total per ton of pig iron	9	[illegible]
Or, per ton of steel ingots		11	2
Or, per ton of rolled steel (rails, girders, sections, bars)		12	6

without taking into account the profits yielded by the sales of the basic slag. What an income for him who would know how to realise it!

I think I have sketched a sufficiently complete outline of the progress realised during some 20 years, in the recovery and application of the by-products of steelworks. Will that progress stop where it is? I doubt it. Every improvement leads to a fresh one, and each day sets the goal of progress further ahead. Just as electricity has permitted of the centralisation of motive power and of its economical distribu-

tion, so the centralisation of the resources of metallurgical gases and their ready transport to the various points of their utilisation bestow upon metallurgical works enormous advantages. To the huge saving in fuel which results from the utilisation of coke-oven and blastfurnace gases for the production of motive power must be added those which are realised by the numerous applications of heating. The study of suitable burners, the general employment of efficient reheaters, and the means of perfect adjustment and complete control, will conduce to even greater saving. Finally, the cost of labour and the running expenses, other important factors of the cost price, are similarly reduced to a proportional extent. By these means our metallurgical industries succeed not only in producing cheaply, for the general need, but they show themselves provident in safe-guarding for future generations the wealth that nature has, with great generosity but not inexhaustibly, implanted in the soil.

APPENDIX.

Calculation of Available Gases.

Coke Ovens.—One ton of coal yields 300 cub. metres of gas, therefore, there is obtained, per ton of coke,

$$\frac{300 \times 100}{75} = 400 \text{ cub. metres (14,126 cub. ft.).}$$

In modern regenerative ovens half the gas is available = 200 cub. metres, or 7,600 cub. ft. Its value ranges from 0·12d. to 0·15d. according to the use made of it. The whole of the available gas can be utilised, for it is possible to store up in gasometers the output made during periods when the steelworks is stopped.

Blastfurnaces.—One ton of pig iron requires for its production one ton of coke, and one ton of coke yields 4,500 cub. metres (159,000 cub. ft.) of gas, of which 40 per cent., or 1,800 cub. metres (63,500 cub. ft.), is available. The gas is, however, lost during the stoppages of the steelworks, because its volume is too great to be stored, and in practice only 1,250 cub. metres (44,000 cub. ft.) can be utilised. Its value is 0·03d. per cub. metre.

GYROSTATIC DEVICES FOR THE CONTROL OF MOVING BODIES.

At a meeting of the Physical Society of London a paper on this subject was read by Dr. J. G. Gray. The paper dealt with a number of new contrivances for stabilising, steering, and forcibly manœuvring moving bodies, such as torpedoes and airships. A number of old experiments were first shown. These included the "gyrostat on stilts" and "gyrostat on gimbals" experiments due to Lord Kelvin, the "crossed bifilar" experiment due to Prof. Blackburn, and a stilt top devised by Prof. Harold Wilson. It was shown that the gyrostatic system in each of these experiments, although exhibiting considerable balancing power, was not possessed of real stability. An unstable body rendered truly stable by gyrostatic action must possess the property that if displaced from the mean position it returns to, and comes to rest in, that position. The mean position is that in which the potential energy of the gyrostatic system is a maximum, and if the system is disturbed energy must be supplied to restore it to the mean, or undisturbed, position. A number of new gyrostatic models were displayed in action, including two-wheeled and four-wheeled gyrostatic motor-cars and bicycles. These all provide examples of gyrostatic systems provided with complete or real stability, and in all the cases shown the stabilising forces are derived from the propelling system. One of the cars shown runs on two wheels in tandem, and is stabilised by a single gyrostat. This gyrostat is mounted in the car and controls the steering mechanism; it forms, in fact, a gyrostatic chauffeur. The model illustrated a new form of torpedo and airship control. A second form of motor-car, which also runs on two wheels in tandem, consists of two parts, a front one and an after one. The front part carries a gyrostat, the back part the propelling mechanism, and the two parts are connected together by means of a vertical hinge. The front part is propelled by the back part, and the arrangement is one of complete stability. The entire system may be manœuvred by means of the gyrostat. It was pointed out that by properly fitting an airship with a gyrostatic "nose" it should be possible to manœuvre forcibly the airship by means of forces derived from the propellers.

THE FLYING-MACHINE FROM AN ENGINEERING STANDPOINT.*

BY FREDERICK WILLIAM LANCHESTER, M.INST.C.E.

(*Continued from page 518.*)

(7) *Motive Power Installation.* We are now faced with the consideration of the motive-power installation. At the present time the internal-combustion engine—more definitely the petrol motor—holds the field. No other prime mover is able to compete either on the score of weight per horse-power or fuel weight economy; there is nothing in sight likely to oust the internal-combustion motor from its supreme position. The relative importance of lightness and economy of fuel is determined by the class of service for which the motor is required. In Fig. 27 curves are given of *weight/horse-power* for various motors; ordinates represent weight of motor plus fuel, abscissæ the duration of the run at full load. It can be seen at a glance from this diagram that for brief periods the weight per horse-power of the engine is the all-important factor, whereas for long runs this becomes relatively less important, the weight of petrol and lubricating oil becoming the main item. On referring to Fig. 27 it will be noted, taking the extremes, that the Gnome engine starts with a very considerable advance over the motor-car engine given for comparison, but after a run of 17 hours at full load, the motor-car engine (represented for the purpose of illustration by the Daimler) by its greater economy has taken the lead. This diagram was prepared by me some three or four years ago (*see* Report of the Advisory Committee for Aeronautics for 1909-10). Many of the aeronautical motors of the present

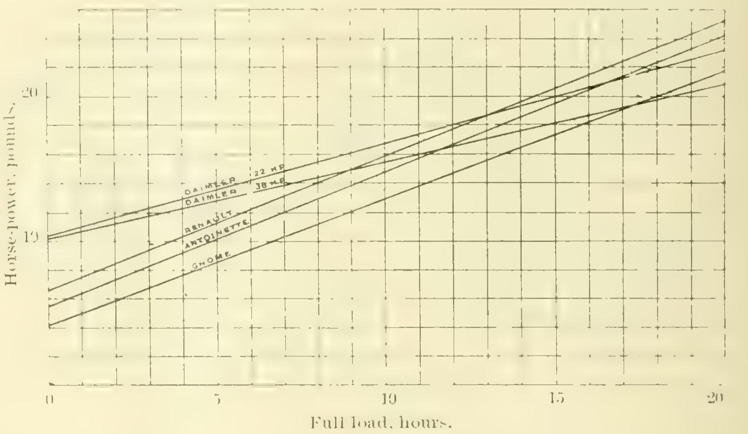


Fig. 27.

day combine with a weight/horse-power factor of about 4, a degree of economy that compares well with the best automobile practice.

Out of a great multiplicity of types of aeronautical engine now on the market there are two types, namely, the rotating engine on the one hand and the light-weight multi-cylinder Vee type on the other, which I consider likely to survive. The rotating type of engine gives the possibility of very complete balance with simplicity of working parts, and so provides the aeronautical constructor with an engine especially serviceable where small machines are concerned, and simplicity and upkeep† are of importance. The rotating engine is, at the present day, reasonably economical in petrol, but is grossly extravagant in lubricating oil, and consequently is at a disadvantage for long-distance work; it will, however, probably hold its own for some time to come in machines for short-distance flying. The rotating engine, also, suffers from some disadvantages on the score of exhaust silencing. The multi-cylinder Vee type, though ordinarily not so light, power for power, as the rotating engine, has many advantages, especially for high power and where long distances have to be negotiated.

It is customary in the rotating engine to employ direct air cooling; it is, in fact, difficult to arrange such an engine

* The "James Forrest" Lecture, 1914, delivered before the Institution of Civil Engineers, May 5th, 1914.

† With the rotating engine in its present state of development, the question of upkeep is not its most satisfactory feature.

with water cooling. The horse-power absorbed in the Gnome engine *incidental to* air cooling is very great; in the original so-called 50 h.p. Gnome (which actually gives very little over 40 h.p. in flight), the power consumed in wind resistance, even on the test stand, amounts to something nearly 6 h.p., and it may be materially greater under flying conditions.

In engines of the Vee type water cooling is in greater favour; the Renault special aeronautical motor is an exception, being cooled by air blast generated by a centrifugal fan. The weight of the water-cooling system when fitted amounts at the best to 0·6lb. per horse-power (with water nearly 1lb. per horse-power), and thus constitutes a serious addition to the weight of the installation. Here again the class of service becomes important. It is evident that for short-distance flying, where engine weight is of paramount importance, it may be better to employ direct air cooling; when, however, a long-distance service is required, it may arise that the weight of the water-cooling system is justified by the saving in horse-power and better fuel consumption.

According to a recent investigation by me* the minimum horse-power expended in cooling, that is to say, the horse-power necessarily expended in cooling, is a function of the area and temperature difference of the surface exposed, and there is some difficulty in providing an air-cooled engine cylinder with sufficient gill surface to keep the horse-power loss as low as desirable; when, on the other hand, water is used as a heat carrier, the rigid limitation as to available surface no longer applies, there is some disadvantage, however, as to temperature difference. In Fig. 28 a diagram is given showing the essential relations between horse-power equivalent of heat dissipated per square foot surface (abscissæ), tangential velocity of air (ordinates), temperature difference, and power absorbed in skin friction. It will be understood the graphs represent the minimum horse-power absorbed based on the assumption that the air is traversing the surface along a stream-line path, and that there is no additional loss of power in eddy making (other than that incidental to skin friction); the honeycomb type of radiator most nearly complies with this condition.

We may now proceed to consider the interrelation and compatibility of engine and propeller. It has already been pointed out that in order to get the full output from a given engine (as is also well known to be the case in marine propulsion), a propeller pitch has often to be selected far from that proper to highest efficiency. The difficulty has (as in the early Wright machine) been met by adopting a reduction gear; alternatively (as also in the Wright machine) a multiplicity of propellers may be employed. It is evident, for example, that, if four propellers be used in place of one propeller, the individual diameter may be halved, and consequently for a given pitch (and therefore revolution speed) the pitch diameter ratio doubled. The original Wright machine furnished a good example of a case in which the propeller pitch diameter ratio was made approximately that of best efficiency, and this result was obtained, in spite of the low velocity of the Wright machine, by a combination of both methods; that is to say, two propellers were used instead of one, and these propellers were geared down from the engine in the relation of 10 to 33.

The incompatibility at present existing between the engine speed and the propeller pitch becomes less as the flight velocity is increased, so that, in the case of an ordinary machine of about 1,400lbs. total weight, the propeller speed (for best efficiency) for a single-screw machine becomes appropriate to the normal engine speed at about 100 miles per hour. Since the loss of efficiency for a fine pitch propeller, even down to half the pitch ratio of best efficiency, is not great, it may be taken that for flight speeds of 50 miles an hour upwards the balance of advantage lies definitely with the direct-coupled propeller; this agrees with experience. A point of interest in connection with propellers of comparatively fine pitch and somewhat reduced diameter, such as commonly in use to-day, is the fact that, with the engine opened fully out, there is very little difference between the thrust and the revolution speed whether the machine is standing or is in full flight (it is commonly reported that the revolution speed does not increase more than 10 per cent. from "standing" to full normal flight speed); the thrust variation also is slight. This fact constitutes the only justification for the static test of aeronautical propellers, frequently resorted to when approximate data are required. There is no doubt that in a propeller of theoretically perfect proportion, or in an existing propeller, if fitted to a machine of less resistance, there would be a far greater response to flight speed variations. Actually this is the case in marine propulsion, where the propeller revolution recorder is commonly found to give more reliable readings than the ship's log.

* Report of the Advisory Committee for Aeronautics, 1912-1913, p. 94.

(8) *Relating to the Design of the Aerofoil.* We shall now proceed to the discussion of the more detailed arrangements and structural features of the machine. First, the aerofoil. The pressure appropriate to least resistance we have already seen to be given by the expression* 0·32 ρV^2 in abs. units, or $\frac{\rho V^2}{100}$ in lbs. per square foot.

Consequently, if w is the weight (in flying order), the area required is $\frac{100\,w}{\rho V^2}$ as appropriate to least resistance.

The above is the whole basis of any initial "lay out"; there are many refinements, however, to be considered which

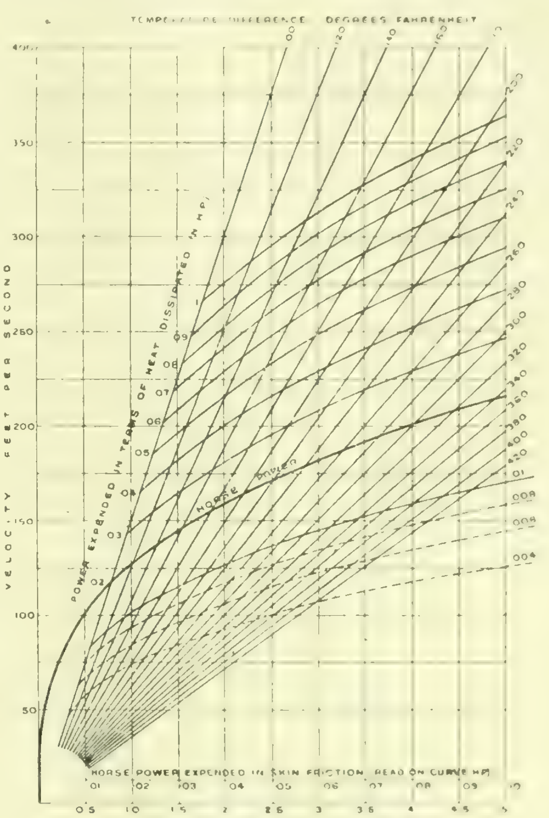


FIG. 28.

enter into the complete problem. The principal of these are:

The fact that part of w is a function of the aerofoil area—the quantity we are determining—means that the best area will be less than given by the foregoing expression. This point has been dealt with by me in "Aerial Flight," 1907,† Vol. I., §§ 171, 194, 195, 196; also more recently by the staff of the National Physical Laboratory.‡

Beyond the above the specification of flight velocity for any machine consists more often than not in the prescription of higher and lower limits rather than of a set fixed speed. Under these circumstances the final values and proportions are based on a lay out of graphs of resistances, thrust, &c., on the lines of the diagrams already given, Figs. 11 and 12.

It is evident from the general character of the resistance velocity curve, as shown diagrammatically in Figs. 11 and 12,

* Compare Figs. 17 and 18 and text. The constant 0·32 is empirical.
† Constable & Co.
‡ Report of the Advisory Committee for Aeronautics, 1911-1912, p. 7[illegible].

that whereas considerable departure may be permitted from the normal velocity of flight on either side of the minimum without incurring appreciable increase in resistance, at the limits of the flight speed range, the slope of the resistance curve is considerable, and there will be sharply defined points at which the resistance is equal to the maximum propeller thrust and no liberties can be taken. It is important to note that at the maximum limit of flight speed the equilibrium of thrust and resistance is stable, whereas at the minimum limit the conditions are those of instability, so that should the machine at any time fall below the minimum, the aeronaut can only recover his power of flight by calling upon gravity to assist him, that is to say, by taking a downward course. If, as when near to the ground (or an obstacle), the downward course is not permissible, the machine will execute an undignified descent, to which the verb "to pancake" has been applied. The critical speed at which this will take place is not necessarily related to the critical "least velocity" angle of the aerofoil.

Briefly, for a given machine, the extent of the flight speed variation is a function of the reserve of thrust over the minimum resistance value, the absolute value of the limits being fixed by the load that the aerofoil is called upon to

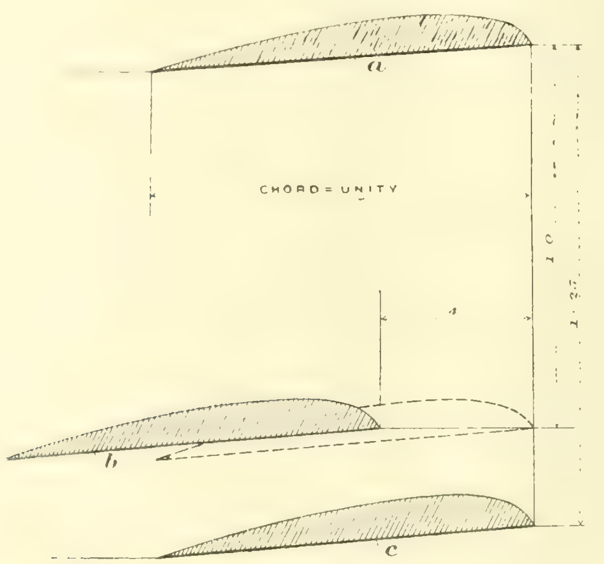


FIG. 29.

sustain. In the case of a high-powered machine, however, the lower limit may be prescribed by the critical angle of the aerofoil.

The choice between monoplane and biplane is, in the main, a question of constructional engineering; there is not a great deal to choose between the two from an aerodynamic standpoint, but with equally good design the monoplane gives a slightly better lift/drift ratio. The interference effect of the two members of a biplane aerofoil has been studied by many investigators. Langley showed, about 1890, that with superposed planes (aspect-ratio = 4) the interference was not serious when separated by a distance equal to their lesser dimension. The results of a more recent investigation by the staff of the National Physical Laboratory are published in the report of the Advisory Committee for Aeronautics for the year 1911-12 (p. 73), from which Table VIII. has been

TABLE VIII.—*Table of Multiplying Factors to obtain Coefficients from the Coefficients for a Single Aerofoil.*

Biplane Spacing, Gap Chord.	Lift Coefficient.			Lift/Drift.		
	6°.	8°.	10°.	6°.	8°.	10°.
0·4	0·61	0·62	0·63	0·75	0·81	0·84
0·8	0·76	0·77	0·78	0·79	0·82	0·86
1·0	0·81	0·82	0·82	0·81	0·84	0·87
1·2	0·86	0·86	0·87	0·84	0·85	0·88
1·6	0·89	0·89	0·90	0·88	0·89	0·91

taken. In addition to obtaining quantitative data for the particular aerofoil chosen (Blériot, aspect-ratio 4), an investigation was also made on the effect of staggering the planes. It is shown to be advantageous to arrange the upper foil in advance of the lower; thus the combination *a b*, Fig. 29, is of the same efficiency as the combination *a c*.

Considering the aerofoil, whether monoplane or biplane, from a structural standpoint, and in investigating the strength of the aerofoil as a whole, it may be treated definitely as an inverted cantilever system. Thus, comparing the stresses in an aeroplane to the stresses in a cantilever bridge, we have the weight of the fusillage with its alighting chassis, motor, passengers, &c., the inverted equivalent of the supporting reaction on the central pier of a cantilever girder. We have the air-pressure force, by which the said load is sustained, distributed along the aerofoil length corresponding to the weights of the outstanding members of the cantilever. We have a variation of pressure from point to point due to gusts, eddies, &c., corresponding to some degree to the movable loads representing traffic over the bridge. In the case of the aerofoil, we have in addition something not represented in the analogy of the cantilever girder, *i.e.*, the weight of the aerofoil itself directly supported by the pressure reaction; we may, however, regard this equal and opposite distribution of weight and pressure as superposed on the main system, and as not contributing to the stresses in the aerofoil members. So far as the analogy to the bridge holds good, it is evident we have a well-known engineering problem which is capable of being treated by well-known methods. In the calculation of stresses of the aerofoil members two alternative methods are in current use; in the one the aerofoil struts are treated as pin-jointed members, by the usual truss-girder construction; according to the other method, in place of the hypothesis of the pin-joint, we have the hypothesis of continuity in the main longitudinals. The first and simpler method has been used by several firms for many years past, and gives results which, under ordinary conditions, are very much on the safe side; the second method has been developed during the last few years by the National Physical Laboratory,* and has been adopted by the Royal Aircraft Factory, and more recently by other manufacturers.

On the pin-joint hypothesis the stresses are solved by the well-known graphic stress diagram; the alternative method is considerably more complex. Reference should be made to the report cited. It is well to remark that though the pin-joint hypothesis gives results usually on the safe side, the extent of the factor of safety so introduced is not one that can be relied upon, and may in special cases be even negative. It is hardly necessary to point out that the more important and vital the problem the less appropriate become methods of an approximate and inexact character.

(9) *Resistance of Struts, Wires, Wheels, &c.*—The question of the resistance of components such as are commonly embodied in the design of existing machines has been studied experimentally at the National Physical Laboratory, at the Aerodynamic Laboratory at Gottingen, and by Mr. F. Eiffel, in Paris. A few results relating to strut sections are given in Fig. 30*a*. The graph *a a* is a plotting from National Physical Laboratory data,† relating to the sections *a*, representing one of the best forms tested, graphs *b* and *c* relating to sections *b* and *c* as determined by Mr. Eiffel.‡ In Fig. 30*a* ordinates represent resistance coefficient in absolute units, also in terms of normal plane (the normal plane unit being that of maximum section). In Fig. 30*b* are given two strut sections designed at the Royal Aircraft Factory. These were reported upon by the N.P.L. as giving less resistance *for given strength* than a number of others submitted. Approximately, strength for strength, these sections gave one-fourth the resistance of struts of circular form.§

The resistance of wires and ropes has been investigated both by the National Physical Laboratory and by Prof. Prandtl of Göttingen. The position may here be summarised by saying that the resistance of a rope or stranded cable, at right angles to the direction of motion, is virtually equal to that of its projected area in normal plane. The resistance of smooth wires is about 20 per cent. less. Both these results only hold good above a certain minimum value of *l*V, which

* Report of the Advisory Committee for Aeronautics, 1912-13, No. 83.
† Ibid., 1912-13, p. 111.
‡ "Resistance of the Air and Aviation," p. 134.
§ Report of the Advisory Committee for Aeronautics, 1911-12, p. 96.

may be taken at about 1·5; thus at 100ft. per second the rule may be taken as applying to cables or wires down to about $\frac{3}{16}$in. (=0·015ft.) diam.*

Another interesting set of determinations, for which we are indebted to the National Physical Laboratory, is that relating to the resistance of alighting wheels; these have been tested both in respect of resistance and lateral reaction.†

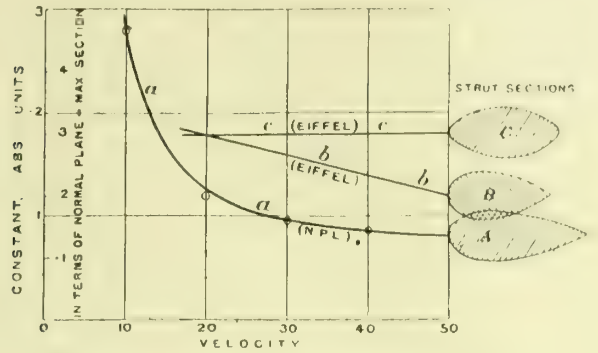


FIG. 30A.

The direct resistance of a 26in. wheel fitted with $2\frac{1}{2}$in. pneumatic tyres appears to be equal to about a third of its projected area in terms of equivalent normal plane, the projected area being taken to be that of the tyre itself. For fuller information reference should be made to the Memorandum cited.

(10) *Vertical Surface.*—One of the quantities of great importance in connection with the type of stability known as rotative or spiral stability is that of vertical surface. It is of great importance to be able to compute with accuracy the effective distribution of vertical surface in any machine, and of recent years considerable attention has been devoted to what we may term the "valuation" of accidental vertical surface. For example, every vertical or inclined strut has a certain directive value which may be expressed in terms of vertical surface. The alighting wheels, especially if of disc form, represent considerable areas of the equivalent vertical surface; even the fusillage (the stream-line body or car) has its equivalent value as vertical surface. It was pointed out by me some years ago that a screw propeller moving other than axially experiences a considerable lateral force. More recently Mr. T. W. R. Clarke has called attention to this action and to the importance of considering the propeller in its capacity as effective vertical surface. It appears from Mr. Clarke's investigation‡ that the propeller equivalent in terms of vertical surface is a very large and serious factor, and one that under no circumstances should be ignored. The Memorandum in question is worthy of careful consideration by all engaged in the design or construction of flying-machines.

A point that should not be overlooked is that the propeller value in the sense under discussion is totally different when under power and when dragging or stationary; this suggests the desirability of locating the propeller as near to the centre of gravity (in the fore-and-aft sense) of the machine as conveniently possible.

(11) *The Dynamic Load Factor and Factor of Safety.*—A matter of importance, and one of a controversial nature, is the factor of safety necessary in order to take care of the many and varied conditions met with by a machine in flight. In the simple case of a machine in horizontal flight in calm weather we know that the load supported by the aerofoil is the weight of the body of the machine and its associated parts, but not including the aerofoil itself, whose weight is directly distributed over the pressure surface; also we know that in the various evolutions a machine is called upon to perform the stresses may considerably exceed the normal, and that variations of effective load are experienced due to wind gusts which it is quite out of the power of the pilot to prevent. Excluding for the time being the latter, we are clearly able to define the worst that the pilot is able to do and specify the factor by which the normal stresses must be multiplied in order to represent the actual stresses; conversely, we may specify arbitrarily a factor of safety, and we may tell the pilot just what he is permitted to do, and just what he cannot undertake without risk. Taking in the first instance the assumption that the pilot is allowed to do his worst—he is to be allowed *to try to wreck his machine.* There are two ways in which he can operate; first, he can drive his machine at the highest possible speed and suddenly alter his elevator to the position corresponding to the lowest possible speed; alternatively, he may take sharp turns involving heavy banking. Now the highest possible speed is the limiting velocity which the machine will acquire falling head first vertically; this, with machines at the present day constructed, may be estimated at about 140 to 150 miles an hour. The lowest velocity in the present sense is the velocity at which the aerofoil is meeting the air at its critical angle (the lowest velocity capable of giving a pressure reaction equal to the weight); this may be taken for the purpose of our argument as 40 miles an hour. If when falling vertically at 140 miles an hour the pilot with absolute suddenness jerks his elevator into the position corresponding to 40 miles an hour, the reaction brought to bear on his aerofoil is $\left(\frac{140}{40}\right)^2$ W, that is to say, approximately, 12 times the weight of the machine. In practice, for the figures given, the maximum load would be diminished, since the elevator cannot be moved with absolute suddenness; and, if it were, the machine could not answer the elevator and alter its attitude to the line of flight immediately. It is probable on the basis of the figures given that 10 W is the maximum effective load that could under any circumstances be brought to bear.

In the case of severe banking, if the machine be banked to an angle θ, the resultant of the weight and centrifugal force is the value W sec θ. I have frequently made estimates of the angle of banking; when a pilot has been making a steep spiral dive the angle rarely exceeds 60° or 70°. Taking 70° as the maximum, the stresses in the machine will correspond to a load equal to 3 W.

From the foregoing it would appear almost certain that in calm weather the pilot, if asked to do his worst, cannot in any manner reach or exceed ten times the stresses due to the static load. Let us take what may be considered an extreme gust. The machine enters air, or is struck by a gust represented by a change of velocity equal to half the flight speed. Assuming the machine has time to swing to its appropriate relative direction under the new conditions, a simple resolution of velocity shows that the worst condition is that in which the direction of motion of the gust is directly opposed to that of flight; in such a case the relative velocity of the machine becomes $1\frac{1}{2}$ times normal, and the effective load on the aerofoil will be $(1\frac{1}{2}^2) = 2\frac{1}{4}$ times normal. In case of the machine being struck by a sudden gust or squall, the load will be considerably higher, but still does not approach the figure 10 obtained on the basis of the pilot suddenly "flattening out" when at maximum speed.

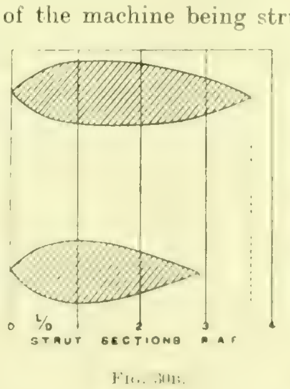


FIG. 30B.

It is evident from the foregoing that a flying machine in the course of its normal usage is liable to stresses many times greater than that of its normal load, and the frequency of these stresses, and the total number of times they occur in the life of the machine, will be related to their magnitude by some empirical law for any given class of service. In such a case it is evident that the term "factor of safety" does not carry its ordinary meaning; if, for example, in the lifetime of a fleet of 100 machines the stresses reach 6 times normal once, and 5 times normal, say, 10 times, and 4 times normal, say, 150 times, it will be certainly sufficient and proper if the designer work to 6 times the normal load for his [illegible]

* Compare Memorandum 40 and 75, Reports of the Advisory Committee for Aeronautics.

† Memorandum 74, Report of the Advisory Committee for Aeronautics, 1912-1913.

‡ Presented to the Advisory Committee by Mr. Mervyn O'Gorman. Memorandum 80, March, 1913. Report, 1912-1913.

limit without using any factor of safety in the accepted sense at all. To do otherwise would be to burden the whole 100 machines with a weight of superfluous material without justification. Whether under these conditions we continue to employ the term "factor of safety" or not* the aeronautical designer must bear clearly in mind that in his particular case his factor has a double function, namely, both to give the margin of strength and durability needed under ordinary conditions of flight, and to provide for abnormal conditions of stress, occasionally even almost to the theoretical limit of the strength of the structure.

In Memorandum No. 96 of the Advisory Committee (not yet included in an annual report), the matter is fully considered, and the extreme probable values are estimated as follows:—

Nature of Contingency.	Computed Dynamic Load Factor.
Gusts	4·0
Banking	1·4
Flattening out	8·0
Looping†	4 to 5

In the report in question‡ the recommendation is made that a factor N be adopted in design not less than 5 or 6, this being considered sufficient to take care of anything likely to happen to a machine with reasonable and proper pilotage. Tests and calculations of the wing spars of different existing machines gave the following results:—

Type.	Value of N.	How Determined.
A	4	By experiment.
B	4	By experiment.
C	5	By calculation.
D	3	By calculation.
E	3	By calculation.
F	4	By experiment.
G	7	By calculation.

The Royal Aircraft Factory have adopted a factor somewhat greater than that recommended in the memorandum in question; a machine (G in above table), of which the aerofoil was tested to destruction, actually recorded 8·4.

In connection with the subject of aerofoil structure it is to be observed that the stress distribution varies considerably under different conditions, namely, at different angles of attack. Referring to Fig. 15 it will be noted that the aerofoil structure commonly includes two longitudinal members, front and rear, respectively, and the proportions of the load borne by each depends upon the position of the centre of pressure and varies with its displacement, which can only be ascertained from experiments on a scale model of the aerofoil itself. This fact needs consideration when computing the maximum stresses on the members in question and the aerofoil structure as a whole.§

The calculation of the aerofoil structure not only comprises the resolution of the main lifting-force distribution, as already discussed, but also entails the calculation of the longitudinal stresses due to line-of-flight, or "drift" forces. These may be quite moderate under normal flight conditions, but may become far more severe at abnormally high speeds. The treatment of this problem does not offer any serious difficulty; it is to-day generally considered the best practice to provide for the edgewise strength of the wing by its own internal diagonal bracing.

(To be continued.)

* This point may perhaps be emphasized by the use of some qualified expression such as dynamic load factor.

† Estimated by me; not in original report. The basis of this estimate is the phugoid chart, Fig. 1, the dynamic load factor is given by the height H in terms of H_{n}, or in the case of looped paths numbered 8 to 12 the value of $\frac{H}{H_{n}}$ varies from 3·6 to 5·5.

‡ If this factor N cannot with propriety be termed a factor of safety, I suggest the term factor of contingency, i.e., the factor of contingency requires to be the equal of greater than the dynamic load factor for which it makes provision.

§ Reference should be made to the Report 96 cited.

TELEGRAPHIC RESEARCH.

THE report of the Committee appointed by the Postmaster-General to consider and report how far and by what methods the State should make provision for research work in the science of wireless telegraphy, has just been issued in the form of a Parliamentary White Paper. The Committee state, after careful consideration, they recommend the adoption of the following scheme: The Government should appoint a National Committee for Telegraphic Research, whose duty it will be to promote generally, in the public interest, both by theoretical investigation and by experiment, the progress of scientific telegraphy and telephony, and to co-ordinate and supplement the work now being done in Government departments interested in such progress. The Government should establish a National Research Laboratory, with a special scientific staff, to undertake, under the direction of the Committee, telegraphic investigation, the result of which should be available for all departments of the public service, and to co-operate with these departments in dealing with the scientific aspects of practical problems arising out of service conditions. This laboratory should be established at Teddington in co-operation with the National Physical Laboratory.

The National Committee, it is recommended, should consist of two members representing the Admiralty, one representing the War Office, two the Post Office, two directly appointed by the Treasury, three appointed by the Treasury on the nomination of the Royal Society, one appointed by the Treasury on the nomination of the Institute of Electrical Engineers, and the Director of the National Physical Laboratory. The two members appointed directly by the Treasury should not be departmental officials, the departments being sufficiently represented on the Committee in other ways. It is also recommended that no member of the Committee should give advice connected with telegraphy or telephony to any commercial firm on any matter connected with the work of the Committee, except with the consent of the Committee, and, in any doubtful case, such consent should not be given without the approval of the department concerned. The Committee should issue an annual report to be laid before Parliament, and they should publish, or authorise the publication of, such researches as they may consider useful for the advancement of science generally, and which are not of a confidential nature. The Committee should have power in its discretion to organise or co-operate in international scientific investigations bearing on telegraphy. With regard to the National Research Laboratory at Teddington, the work should be limited to research and experimental investigations under the direction of the director, who would receive his instructions from the National Committee. The probable total annual expenditure entailed by the adoption of the scheme would be £4,800. The Committee attach so much importance to the urgency of research work that they recommend an immediate vote of £4,000 in the present year. The new scheme, they state, has been considered and approved by Lord Rayleigh, Sir Oliver Lodge, and the Secretary of the Royal Society.

Serious Gas Explosion on a Battle-ship.—An explosion of coal gas occurred in one of the coal bunkers aboard the battle-ship "Bellerophon" at Cromarty on Friday, the 5th inst., resulting in four of the stokers being badly burned.

A Disastrous Marine Boiler Explosion.—According to the "Engineering News," the boiler explosion on the Old Dominion steamer "Jefferson" off Cape Henry on the night of May 11th resulted in the death of 10 men. Inspection of the boiler after the accident indicated that low water was the cause. The furnace crown had sagged and the upper right-hand portion of the tube sheet was blown entirely away from 12 tubes. The ends of the stay tubes were in good condition. The one from which the sheet blew entirely away was not distorted and the hole in the sheet was perfect, except that it was enlarged just enough to allow the pressure (190lbs. normally) to force it over the beaded tube ends. The ashes were being removed at the time of the accident and on this ship the pressure usually dropped 30lbs. when this work was being done.

INDUSTRIAL AND TRADE NOTES.

Shipbuilding on the Clyde.—During the month of May, 27 vessels, aggregating 40,012 tons, were launched on the Clyde. As compared with the same month in the three preceding years these figures cannot be termed satisfactory. In fact, they are the lowest for May since 1900, and only five times in the past 20 years have the returns been lower. Taking the output of the first five months of this year, a decrease of exactly 100,000 tons is shown as compared with the corresponding period of 1913. As regards new contracts, very few have been booked, and the outlook is far from promising.

The Granting of Patents in Brazil.—To conform with the Brazilian Patent law it is necessary to supply the "Directoria Geral de Industria e Commercio da Secretaria de Estado dos Negocios da Agricultura, Industria e Commercio," Rio de Janeiro, with documents to prove the actual working in Brazil of industrial inventions for which privileges have been given by patents granted from 1898 to 1911. The latest date at which such documents will be received is October 21st. If these proofs are not furnished by the date mentioned the patent will be declared null and void, in accordance with the law which regulates the granting of patents.

Coalite.—The shareholders of the British Coalite Company, who consented to a reduction of their capital last autumn, are now asked to take up an issue of 50,000 6 per cent. participating preference shares of £1 each at par in the Barnsley Smokeless Fuel Company, which has been formed to run a smokeless fuel plant at the Old Silkstone Collieries, near Barnsley, under the patents and processes of the British Coalite Company. This plant will only be capable of treating 200 tons of coal per day, but the directors of the Coalite Company point out that they have now under consideration offers from several colliery companies and other concerns for the erection of coalite installations.

Trade Openings in Mexico.—Mr. G. E. S. Watson, British Vice-Consul at Mazatlan, Mexico, in his annual report, just issued, states that he has been informed by the manager of one of the largest importing houses in this district, who spent some years in Sheffield, that British steel, tinplate, galvanised and corrugated iron, tools, and files should be able to meet all competition here; it is only within the last three years that the United Kingdom has been superseded in these lines. There should also be openings for mining machinery and crucibles, gas engines, and pumps for irrigation and other purposes. It would appear that one of the disadvantages in dealing with British firms is that merchants must either deal with agents or send cash, whereas United States firms (apparently more cognisant of Mexican business customs) give terms direct and a special discount for cash.

Oil Resources of Peru.—According to the American Consul-General at Callao, there are four leading oilfields in Peru. The Negritos or Talara field lies on the coast, about 40 miles north-west of Paita, which is the port for the Department of Piura. Some 25 miles inland from Negritos, the centre of boring operations on the ocean side, is La Brea, where a black and very viscid stuff like asphalte is found. The Zorritos field lies about 25 miles south of Tumbes in the extreme northern part of Peru, also on the ocean. The quality of the Zorritos petroleum and its by-products is excellent. The Lobitos field is situated in the Department of Piura. The fourth most important field is that in the Department of Puno, near Huancane. Petroleum is also found in the districts of Pirin, Chimbote, Jauja, Huancavelica, and Ica. In fact, it seems to extend through the entire mineral belt of Peru, at intervals, from Tumbes in the north to Lake Titicaca on the Bolivian frontier in the south. The Peruvian wells along the coast run from out in the sea to many miles inland, varying in depth from 250ft. to 3,048ft. The total production for 1910 was: Crude oil, 175,000 tons; kerosene, 1,050,000 galls; gasoline and benzine, 155,000 galls.

Machine-tool Contracts.—The Machine Tool and Engineering Association, Ltd., has formulated revised conditions of tender for the benefit of its members. The more important of these are: (1) Prices are quoted for acceptance within 30 days, subject to purchasers' credit being approved. Prices given for machines in stock are subject to same being unsold when order is received. (2) Photographs and other illustrations or advertising matter represent generally the goods offered, but are not binding in details, as improvements are constantly being made in design. (3) All weights, measurements, and powers given in estimates are stated as correctly as possible, and any slight deviations shall not be taken to vitiate the contract, or form grounds for any claim against us. (4) The time for delivery shall be reckoned from the date of receipt by us of complete instructions, approval of drawings, &c., necessary for the execution of the work. Unless a written guarantee specifying the liquidated damages has been given by us, no liability whatsoever for inability to deliver to time will be accepted by us, whether on account of direct or consequential damages. (Such guarantee should contain provisions to provide that the penalty should not be paid if delay is due to strikes, lock-outs, civil commotion, war, fire, act of God.) (5) All goods are supplied and guaranteed against defective workmanship and material for a period of six months from date of invoice, and parts which be proved to be defective will be replaced, but shall not form the subject of a claim for labour or other expenditure made upon them, nor shall we be liable for any direct or consequential damages arising therefrom. (6) Unless otherwise provided for by this tender, it is a condition that we are not liable for any damage or loss, either consequential or direct, that may arise after the goods have left our premises.

Mineral Oil Industry of the Caucasus.—A report by H.M. Consul at Batoum (Mr. P. Stevens) on the trade of that district in 1913 states that, owing to the large falling off in the output of the Baku, Cheleken, and Maikop oilfields, the production of petroleum in the Caucasus in 1913 showed a decrease of 211,387 tons as compared with the previous year. The decline is attributed principally to the strikes at, and the exhaustion of, the wells in the Baku area. The number of feet drilled in 1913 was 219,625, against 192,423 in 1912. According to a review of the petroleum industry in 1913, published by the Baku Petroleum Association, the following changes took place in the production of crude oil during the year as compared with the figures of 1912. In order to show the leading position Russia held in the oil industry of the world in 1901 the figures of the production of that year are also given; of course they are only approximate, but in view of the enormous importance which oil has assumed within comparatively recent years, they are of some interest:—

Country.	1901.	1912.	1913.
	Tons.	Tons.	Tons.
United States	8,951,000	29,161,000	31,984,000
Russia..............................	10,984,000	9,324,000	9,113,000
Mexico	—	2,450,000	2,968,000
Roumania	226,000	1,774,000	1,839,000
Dutch East Indies	613,000	1,452,000	1,645,000
Austria-Hungary	451,000	1,177,000	1,016,000
Other countries..................	484,000	1,709,000	1,919,000
Total	21,709,000	47,047,000	50,484,000

According to these figures, the world's production advanced in 1913 over 1912 by about 7·4 per cent., whereas Russian production decreased by about 2·3 per cent.

The Panama-Pacific International Exposition at San Francisco.—The Palace of Machinery of the Panama Pacific International Exposition is now completed, and the whole of the space, covering an area of 369,600 sq. ft., allotted. The exhibits will, it is claimed, comprise the finest collection of electrical and machinery exhibits ever assembled under one roof, and the exhibitors are co-operating with the Department of Machinery in associating their exhibits with others so as to permit of complete operation and demonstration of the working of the various machines and electrical exhibits. On April 1st preliminary work was started on the installation of the first exhibit, a 500 h.p. marine Diesel engine, by the Busch-Sulzer Bros. Diesel Engine Company. The latest and most modern-approved methods of illumination will be displayed in connection with the exhibits in the Palace of Machinery, and will be of interest to the layman as well as to the student. One phase will be especially interesting—the isolated electric house-lighting systems for farm use compared with the most complicated systems in use for city lighting. The testing of high-potential insulators and transformers will be made possible by the arrangements which have been made with the largest manufacturers of high-voltage testing apparatus, and many spectacular effects have been prepared by the use of such instruments. A feature of the Palace of Machinery will be the methods employed for the convenience of the visitors. A number of plans are now being tested to ensure engineers and students the opportunity to make a careful examination of each exhibit in privacy and comfort. Reception spaces will be provided in connection with each exhibit and equipped with suitable fixtures which will enable technical visitors to prepare notes on the various features. All of the working exhibits—and it is now certain that a large percentage will be in actual operation—will be equipped with the latest "safety first" devices, and these guards will form one of the most interesting exhibits to the engineer and manufacturer. The gates of the Exposition will open on February 20th, 1915, and will close on December 4th, 1915. Nine of the 11 principal exhibit buildings are now complete, and the others will shortly be finished.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1913.

Joints and couplings for pipes and tubes. Calthrop & Churchill. 3930.
Manufacture of zinc. Ferrere. 3965.
Treatment of iron. Dismore. 4292.
Process for the production of cast iron. Gregory. 6530.
Carburetters for internal combustion engines. Brown, and Brown and Barlow, Ltd. 8838.
Centrifugal pumps. Siemens-Schuckertwerke Ges. 9354.
Induction pipes of internal-combustion engines. Betteley and Baker. 9802.
Anti-friction metals. Billington. 11138.
Two-cycle internal-combustion engines. Junkers. 11378.
Boiler tube cleaners. Lumb. 11389.
Piston packing. Allen. 11480.
Regulation of lifts and elevators. Tessieri. 11533.
Machines for use in mining coal. Mavor & Coulson, Ltd., and Mavor. 11554.
Internal combustion engines. Kilgore. 11565.
Graded service automatic or semi-automatic telephone system. Baron. 11590.
Feed-water regulators for steam boilers. Hough. 11694.
Cooling the pistons of internal-combustion engines. Burn. 11719.
Steam superheaters and generators. Cruse. 11813.
Cooling of the pistons of internal combustion engines. Boys and Stinson. 11826.
Neck ring or bush for piston and valve rods. Wigham & Johnson. 11868.
Change speed gear. Puschtschin. 12099.
Screw or rotary pumps. Marks. 12101.
Megass furnaces. Stirling Boiler Company. 12141.
Speed indicating and recording devices. Marker. 12251.
Means for indicating the quantity of fluid flowing through a pipe. Hodgson. 12255.
Carburetters for internal-combustion engines. Huguelet. 12344.
Conveyers or screens for coal. Berrisford. 12419.
Valves. Muntz. 12445.
Process for making punches of steel. Stamm. 13217.
Manufacture of metallic articles, such as gun-barrels and turbine-blades. Pasel. 13414 and 13415.
Lathe carrier. Death. 13699.
Valve-spring lifters for poppet valves. Rowe. 14339.
Steam boiler furnaces. Ramsbottom. 14439.
Carburetters for internal-combustion engines. Lelarge. 14687.
Appliances for automatically stopping trains. Green. 14735.
Pumps for use with internal-combustion engines. Renée. 14859.
Controlling devices suitable for the cylinders of locomotives. Stenning & Schmidt's Superheating Company. 16623.
Guarding of revolving shafts and pulleys. Jones' Sewing Machine Company and Hall. 17044.
Variable-speed friction gearing. Cowey. 17117.
Gas analysis apparatus. Taplay & Abady. 17676.
Milling machines. John Holroyd & Co., and Gartside. 17749.
Variable-speed and reversing gearing. Haines. 18083.
Purifying steel. Humbert. 18856.
Chucks. Miller. 19240.
Universal self-centring jig. Hatton. 19393.
Process and method of superheating steam. Geoghegan. 20374.
Internal gauges. Sandoz-Moritz. 21009.
Turret lathes. Herbert & Vernon. 21637.
Steam turbines. Mensforth. 22148.
Circular saw blades for cutting metals cold. Rocour. 22929.
Vacuum brake apparatus. Luard. 24067.
Torches for welding and cutting with gaseous fuel. James. 24238.
Turbines. Knourek. 24489.
Valve-mechanism for internal combustion engines. Sanchez and Baradat. 24568.
Railway signalling apparatus. Kehrhahn. 24579.
Safety signalling and controlling devices for railways. Cooper. 25851.
Automatic railway safety devices. Ringbom & Von Willebrand. 26385.
Devices for notching metal bars of angle, tee, and like shape. Taylor & Taylor. 26596.
Two stroke-cycle internal combustion engines. Maschinenfabrik Augsburg-Nurnberg Akt.-Ges. 27232.
Two-stroke internal-combustion engines. Every-Clayton. 28116.
Bushes for wheels and pulleys. Garside. 28937.
Coke ovens. Schuster. 29494.
Metal furnace. Hall. 29525.

1914.

Flexible couplings. Francke. 185.
Regulating superheat in connection with steam generators. Babcock & Wilcox, Ltd., and Rosenthal. 211.
Water gauges. Labay. 215.
Clutch devices. Milham. 368.
Core-drawing mechanism for use in the casting of metals. Ferman and Ferman & Co. 1416.
Boiler feed valves. Crawford. 1730.
Tool for withdrawing or extracting tubes. Crockatt. 1830.
Controlling of electric motors for ship propulsion and means therefor. Siemens-Schuckertwerke Ges. and Hulss. 4308.
Automatic coupling for railway cars. Liedtke. 4420.
Valve-mechanism for internal combustion engines. Reno & Bois. 4863.
Tool chucks or sockets. Electric and Ordnance Accessories Company and Ellis. 5648.
Expansion joints for piping. Wagner. 6094.
Steam superheater systems. English, Hannan, & Mills. 6600.
Packed joints for pipes and tubes. Fried. Krupp Akt.-Ges. 6730.

ELECTRICAL, 1913.

Incandescent body for electric glow lamps. Just. 8956.
Commutators for dynamos. Zenk. 11886.
Automatic or semi automatic graded service telephone system. Baron. 11888.
Telephone systems. Automatic Telephone Mfg. Co. 11998.
Coil for electrical purposes. Wade. 12168.
Storage battery. Rankin, and Electrical Power Storage Company. 12527.
Electric switches. Meiklejohn. 13588.
Electrical elements for cooking purposes. Venner. 13989.
Electric switches. Turner. 14112.
Protective devices for electric distribution systems. British Thomson-Houston Company. 15550.
Regulating systems of electrical distribution. British Thomson-Houston Company. 16054.
Boxes for electrical contacts. Bonham. 19085.
Arc light carbons. Ayrton. 22319.
Electric motor-driven vehicles. Von Kando. 25834.
Automatic regulating devices for dynamos. Robert Bosch. 26906.
Electric switches. Davidson. 29821.

1914.

Electrical condensers of the ring type. Hartmann & Braun Akt.-Ges. 4215.
Electric switch. Von Hutschler & Ordon. 7562.

METAL QUOTATIONS.

TUESDAY, JUNE 9TH.

Aluminium ingot	86/– per cwt.
,, wire, according to sizes, &c. ......from	107/4 ,,
,, sheets ,, ,, ... ,,	112/– ,,
Antimony	£27/–/– to £28/–/– per ton.
Brass, rolled	$7\frac{1}{8}$d. per lb.
,, tubes (brazed)	$9\frac{5}{8}$d. ,,
,, ,, (solid drawn)	$7\frac{7}{8}$d. ,,
,, ,, wire	$7\frac{1}{4}$d. ,,
Copper, Standard	£61/15/– per ton.
Iron, Cleveland	51/3 ,,
,, Scotch	57/3 ,,
Lead, English	£19/10/– ,,
,, Foreign (soft)	£19/10/– ,,
Mica (in original cases), small	6d. to 3/– per lb.
,, ,, ,, medium	3/6 to 6/– ,,
,, ,, ,, large	7/6 to 11/– ,,
Quicksilver	£7/–/– per bottle.
Silver	$25\frac{15}{16}$d. per oz.
Spelter	£21/7/6 per ton.
Tin, block	£139/–/– per ton.
Tin plates, I.C.	12/3 per box.
Zinc sheets (Silesian)	£24/10/– per ton.
,, (Stettin; Vieille Montagne)	£24/12/6 ,,

Personal.—Mr. J. F. M'Intosh, M.V.O., who has retired from the position of locomotive, carriage, and wagon superintendent of the Caledonian Railway Company, was on the 28th ult. presented by the staff in the locomotive department with a silver tray and set of bowls and flower-vases in appreciation of his having completed 52 years' service with the railway company, and of the high position which he has attained in the railway world. Mr. W. Pickersgill succeeds Mr. M'Intosh.

The Mechanical Engineer.
AN ILLUSTRATED WEEKLY JOURNAL Vol. 33, No. 856

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Telegrams: "Scientific," Manchester.
Telephone No. 6055 City.

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Advertisements, displayed, for insertion in current issue should reach our Manchester office not later than first post Tuesday morning, and small prepaid advertisements not later than first post Wednesday morning.

Institution of Mechanical Engineers.

FOLLOWING their departure from custom initiated by the reading of Prof. Ripper's paper at Manchester in November last, and influenced doubtless by the criticisms evoked by the informal meeting of local members called by the Council at the same time, the Institution of Mechanical Engineers have taken a new step with regard to the issue of their proceedings, and intimated their intention to adopt certain changes which should do much to meet the criticisms which have been levelled, and to which we gave some reflection at the time (*see Mechanical Engineer*, November 28th, p. 497, Vol. XXXII.). It will be remembered that we strongly urged a policy of devolution in order to maintain touch between the parent society in London and the virile local centres of mechanical engineering which have sprung into existence, particularly in the northern parts of the country, during the last quarter of a century, and this course we note the Institution propose to pursue, by making arrangements whereby papers read in London may be simultaneously read in any other centre where members desire. To carry out this arrangement it is proposed to appoint a member of the Council—which includes representatives of various engineering centres in the country—to undertake, in conjunction with a local correspondent, the duties pertaining to the reading of papers and the conducting of discussions in his particular district, and subsequently to transmit the accounts of the local proceedings to the secretary of the Institution for inclusion in the transactions or in the new journal of the Institution, which is another feature of change, and which, members will be aware, made its first appearance during the past week. This arrangement, if infused with vitality, should materially promote the activity and influence of the Institution in northern centres, and dissipate the complaints to

which rather strong expressions were given at the Manchester meeting. The new journal will also help to a more intimate and up-to-date touch between the head-quarters and local centres. It is intended to issue this eight times a year, and as far as the current year is concerned, the "Journal" will be supplementary to the proceedings, though next year the somewhat spasmodic and belated publications of the latter will be replaced entirely by the more frequent and regular issue of the "Journal," the general scope of which is indicated by the number just published. Apart from the reproduction of the paper on the electric driving of rolling mills, which has been read, it includes a précis of each of the papers to be read at Paris next month, and thus tends to stimulate in advance interest in the proceedings, and in all probability attendance at that meeting. At all events it enables members to form some idea as to the quality of the mental food which will be provided and whether a more intimate participation in it is likely to be advantageous. We compliment the Institution on the readiness they have displayed in considering the various suggestions that have been put before them with a view to improve the sphere of its activities, and trust that all members will do their best to second the efforts of the Council.

Foundry Regulations.

As an outcome of a special enquiry instituted by the Home Office, and of a subsequent joint discussion between employers and workmen, a number of special regulations will in future be applied by the Home Office to foundry operations with a view to diminish the abnormal accident rate from burns and lifting tackle that has hitherto prevailed. The causes are well known to those who have experience of foundry work, and were set forth in our issue of February 13th last (*see* p. 137 ante). The accidents from burns are no doubt largely due to defective gangways and inadequate spaces between moulding boxes, along which shanks and ladles have to be carried by workmen during casting operations, and could doubtless be greatly diminished by the wearing of some suitable protecting footgear. This was generally admitted at the joint discussion, though there was a difference of opinion as to who should bear the expense. This, however, is now settled, for the provision of foot protection for the men will be compulsory in all moulding shops when men are engaged in casting operations, and we have not the slightest hesitation in stating that, in conjunction with wider gangways, it will greatly diminish the accident rate that has hitherto prevailed from burns. Hoisting tackle has not, in the foundry, received the attention it deserved, and such precautions as periodical examination or annealing has been subject to no definite rule, with the result that chains have too often been worked on until they broke, and then it was a happy chance if no one was injured. This, however, is now to be altered. All chains in future will require to be tested and periodically examined, and all ½in. and smaller chains reannealed or fired once at least within every six months, while larger chains will require to be annealed when in the opinion of the factory inspector it is necessary.

The Concrete Institute.—Prof. Henry Adams, M. Inst. C.E., M. Inst. M.E., F.S.I., &c., was appointed president of the Institute for the ensuing two years of office, at the fifth annual general meeting recently held. The Institute medal for the 1912-13 session, which is awarded annually for the best paper read in the previous session, was presented to Mr. S. Bylander for his paper entitled "Steel-frame Buildings in London."

LARGE TURBO-GENERATORS.

SOME particulars are given in "The Electrical Review and Western Electrician" for May 30th of the new electric power generating station of the Philadelphia Electric Company, which are of special interest in view of the fact that it will be equipped with the largest turbo-generator in the world. It is a polyphase unit of 35,000 kw. capacity, and is at present under construction at the works of the General Electric Company, Schenectady, together with another almost equally large unit of 30,000 kw. capacity. The 35,000 kw. 60-cycle turbo-generator is wound for 13,200 volts, three phase. It has six poles and will run at 1,200 revs. per minute. The amperes per phase at 90 per cent. power factor will be 1,460 and the internal reactance 10 per cent. The exciter will be a direct-connected 150 kw. six-pole 250-volt shunt-wound machine, operating at 1,200 revs. per minute. The 30,000 kw. 25-cycle alternator is wound for 13,200 volts, three phase, and runs at 1,500 revs. per minute. It is a two-pole machine, the amperes per phase at 100 per cent. power factor being 1,313. The internal reactance is 8 per cent. and the external reactance 4 per cent. It has a direct-connected 250-volt shunt-wound exciter of 110 kw. capacity. It is a six-pole machine, operating at 1,300 revs. per minute. Each of these machines will have temperature coils located permanently in the stator windings and connected to recording instruments located at the switchboard. This will enable the operators at all times to know the temperatures of the high-tension windings, which is an additional safeguard in the operation of the machines. The armature insulation tests (200 per cent. of normal voltage) for each alternator will be 26,400 volts and field insulation tests 1,500 volts. The 500 kw. turbo-exciter set comprises a Curtis steam turbine operating at 5,000 revs. per minute and a geared shunt-wound six-pole 250-volt direct-current generator operating at 900 revs. per minute.

Especial interest attaches to the over-all dimensions, weights, and speeds of rotation, which are given in the accompanying table. The turbines of the Curtis type will be supplied with superheated steam of 215lbs. pressure at the throttle and superheat not to exceed 200° Fah. through a 20in. throttle valve. Under steam conditions given above and with a back pressure not to exceed 1·5in. of mercury absolute, the guaranteed consumption of the two machines will be as follows:—

Size of turbine in kilowatts.	Steam consumption in pounds per kilowatt-hour.
30,000 (25 cycles)	12·45 at 15,000 kilowatts. 11·9 at 22,500 kilowatts. 12·75 at 30,000 kilowatts.
35,000 (60 cycles)	12·9 at 15,000 kilowatts. 11·9 at 25,000 kilowatts. 12·0 at 30,000 kilowatts. 12·6 at 35,000 kilowatts.

The main bearings of each machine will be 24in. diam. by 52in. in length, and will be water-cooled by the circulation of 60 galls. of water per minute for the 30,000 kw. machine and 100 galls. per minute for the 35,000 kw. machine, both at minimum pressure of 20lbs. per square inch from turbine-driven pumps. For lubrication of turbine bearings 40 galls. of oil per minute will be required at minimum pressure of 30lbs. per square inch. In each instance this oil is drawn from a tank of 15 barrels capacity cast into the base of the machine, and is normally circulated by a geared pump driven from the shaft of the machine itself. There will also be provided a duplex steam pump of ample capacity for use in case of trouble with the gear pump. The turbine governors will be of the usual hydraulic pattern as made standard for Curtis horizontal units, and the valve gear will be of the usual mechanical type, controlled by the hydraulic governor.

The condensers, which are the largest ever built for stationary practice, will be of the two-pass radial-flow surface type, each containing 50,000 sq. ft. of cooling surface. The tubes will be 1in. diam. and of No. 18 B.W.G., and will be arranged eccentrically within the shell in circular rows. The air will be removed from the centre in order to give the steam a minimum path of flow through the condenser tubes. By means of the counter-flow principle, the condensate will be allowed to pass down over the hottest tubes and will be removed at a temperature within a few degrees of

the exhaust steam. The circulating water to each condenser will be supplied through three-rotor centrifugal geared turbine-driven pumps. For each generating unit there will be installed two of these pumps, with a maximum capacity each of 37,500 galls. per minute. Besides these, there will be provided one additional pump of like type and capacity, as a spare unit coupled for emergency service to either condenser. The reduction gear used for these pumping outfits will be of the well-known herringbone type with a gear ratio of 9 : 1, the turbine operating at 2,880 revs. per minute and the pump at 320 revs. per minute. The injection water, which will be delivered to the condenser through a 48in. pipe, enters at the bottom and discharges from the top, through a pipe of similar size, and the end of this discharge pipe will be sealed so as to form a perfect siphon system. This arrangement of piping reduces the actual work performed by the circulating pumps to that required to overcome the friction of the tubes and piping.

Turbine Installation Data.

Size of turbine in kilowatts.	Length over all in feet.	Extreme width in feet.	Extreme height from floor in feet.	Weight in 1,000,000lbs.	Speed of rotation in revs. per minute.	Throttle valve. Inches diameter.	Diameter in feet of exhaust outlet to condenser.	Diameter in inches of free exhaust to atmosphere.
20,000 (25-cycle)	59·38	19·66	15·18	·975	1,500	18	14 × 12	36
35,000 (60-cycle)	63·16	21·42	15·85	1·2	1,200	20	14 × 12	36

The condensate pumps will be of the two-stage centrifugal type, direct-connected to steam turbines; each generating unit is to be provided with two pumps, the capacity of which will be 1,500 galls. per minute each. The water of condensation which passes through these pumps will discharge into a "sweet water" tank from which it will flow by gravity into a boiler feed-water heater of the open type. As a further precaution and warning to the operating engineers in case of failure of the condensate pumps, a high-water alarm will be connected to each condenser; this consists essentially of an electro-mechanical device which closes an alarm circuit when the water in the condenser base has reached a predetermined and abnormal level. The air pumps will be of the well-known Le Blanc type direct-connected to steam turbines; these pumping outfits also will be in duplicate, and will be placed immediately below the condensers. The "hurling" or sealing water required will be supplied by circulating pumps and be discharged directly into the discharge tunnel.

The boiler equipment of the new station will consist of 20 Babcock & Wilcox water-tube boilers, each 32 tubes wide, 14 tubes high, by 20ft. long, and four steam and water drums each 42in. diam. by 22ft., 3·25in. long. The superheater will be of standard Babcock & Wilcox type. Some idea of the size of the furnaces may be obtained from the fact that the depth of furnace is 8ft. 7·5in., its width 19ft., and the height from floor line to lower row of boiler tubes measured at the front header is 11ft. Each boiler is guaranteed to evaporate 60,000lbs. of water per hour from a temperature of 160° Fah. to a pressure of 250lbs. per square inch and a maximum temperature of 600° Fah. There will be two separate and distinct coal-storage bunkers, each having a capacity of 3,500 tons, and each bunker will be divided longitudinally into four sections by fireproof partitions to prevent the spread of any combustion which might occur. From these bunkers the coal flows by gravity through pipes to the stoker hoppers. Each boiler will be equipped with one ten-retort underfeed automatic stoker of the Taylor type with extension grate and automatic clinker crusher and feeder, the ashes dropping directly into ash hopper located immediately below the furnace. For air supply to each furnace there will be provided one multivane blower driven by a 60 h.p. steam turbine through a reduction gear of the herringbone type. Turbine speed will be 3,600 revs. per minute reduced to 510 revs. per minute at the fan. Each blower will deliver 35,000 cub. ft. of air per minute against a static pressure of 5in. of water in the wind box. When operating under these conditions the water-rate guarantee of the turbine is not to exceed 28lbs. per brake horse-power hour.

CHUCK FOR DRILLS AND REAMERS.

A DESIGN of chuck for use with drills, reamers, and similar tools has recently been patented by the Electric and Ordnance Accessories Company, Ltd., of Cheston Road, Aston, Birmingham, in conjunction with L. M. Ellis. This is shown in the accompanying cuts, Fig. 1 being a longitudinal section, Fig. 2 a transverse section taken along the line X—X of Fig. 1, and Fig. 3 a transverse section taken through the driving flats of the tool holder. The chuck body is provided at one end with a tapered shank A for insertion into a correspondingly tapered socket of the machine in the usual manner. The tool holder is of cylindrical form externally, and has its inner end provided with conical surfaces B which engage with correspondingly-shaped surfaces on the interior of the chuck body. The tool holder is tapered internally in the usual manner for the reception of the tapered shank of the tool, a transverse slot G being formed at the inner end of the tool holder for the usual tang on the shank of the tool to engage

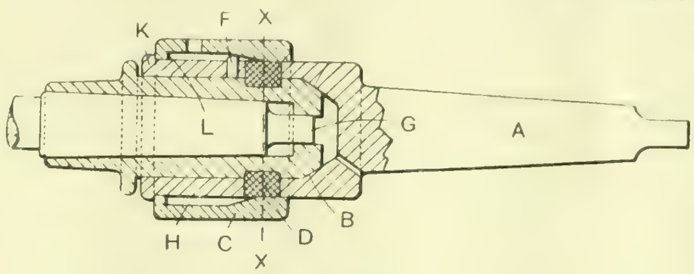
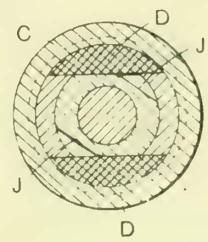


FIG. 1.



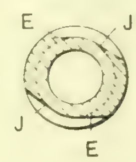


FIG. 2. FIG. 3.
CHUCK FOR DRILLS AND REAMERS.

with. C is the adjustable sleeve which is capable of sliding lengthwise to a limited extent, and is formed with an internal recess H, into which the driving segments D enter when the sleeve is at the limit of its movement in one direction, and thus permit the tool holder to be withdrawn from the chuck body. E and J are the two pairs of parallel and oppositely arranged flat surfaces of the tool holder with which the driving segments D engage when the sleeve C is moved to the extremity of its position in one direction as shown in Fig. 1. By forming the tool holder with these two pairs of parallel flat surfaces arranged in this manner provision is made for the ready and easy engagement of the driving segments therewith, two pairs of engaging surfaces being provided instead of one as heretofore.

In order to limit the movement of the sleeve C in the direction for causing disengagement of the driving segments D from the driving flats E or J on the tool holder the chuck body is provided with a projection or pin F which may be screw threaded to engage with a correspondingly threaded hole in the chuck body. The pin is inserted in the chuck body after the sleeve C has been placed in position thereon, and to enable this to be accomplished the sleeve is provided with a hole through which the pin can be passed. By adjusting the sleeve so that the hole coincides with the screw threaded hole in the chuck body the pin can be screwed into position until it stands below the inner surface of the wall of the recess H in the sleeve, thereby allowing the latter to be freely moved within the limited distance provided by the pin F in one direction and the collar K in the opposite direction co-operating with the shoulder L of the sleeve.

The Institution of Civil Engineers.—The annual conversazione will be held at the Institution on Thursday evening, July 2nd, from 8-30 to 11-30.

SOME RECENT IMPROVEMENTS IN CASE-HARDENING PRACTICE.*

BY HENRY L. HEATHCOTE, B.SC.

It is obviously out of the question for any one man—especially if he be a works' chemist and beset daily with demands only adequately to be met by omniscience—to attempt to give a comprehensive account of recent improvements as suggested by the title of the present paper, as for the most part these are known only to the hardening staff of the several works where they have been evolved, and very few filter through to publication. Not much information on the subject chosen is to be found in the English literature; and the best way for the author to treat it appears to be for him to give an account of what has been done at Rudge-Whitworth Works; of how the problem presents itself and how a solution has been sought; hoping that a frank statement may elicit from other members some account of their own experience and recent improvements.

Even to the casual visitor and the superficial observer it must be obvious that, generally speaking, the machine shop is ages in advance of the hardening shop. In the machine shop are to be found highly differentiated machine tools, each the last word in scientific design and construction, embodying the best engineering knowledge and skill of many nations. The tools, as often as not of high-speed steel, and the grinding

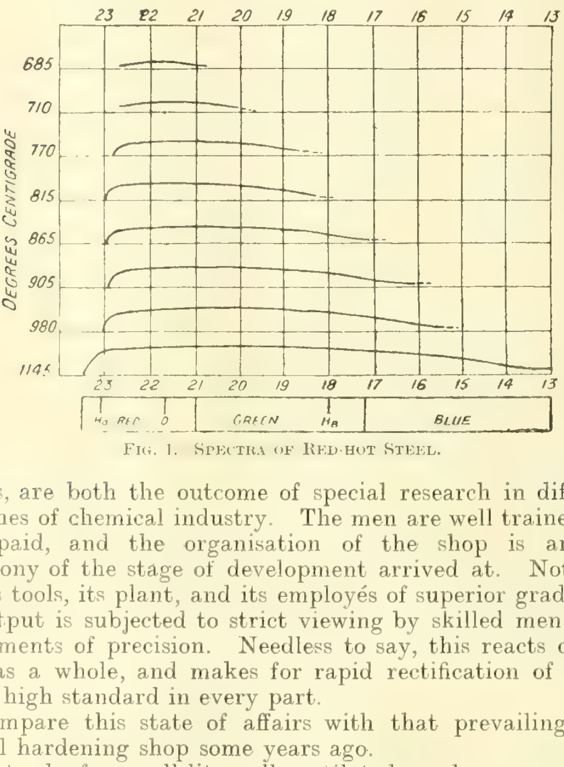


Fig. 1. Spectra of Red-hot Steel.

wheels, are both the outcome of special research in different branches of chemical industry. The men are well trained and well paid, and the organisation of the shop is another testimony of the stage of development arrived at. Not only are its tools, its plant, and its employés of superior grade, but its output is subjected to strict viewing by skilled men using instruments of precision. Needless to say, this reacts on the shop as a whole, and makes for rapid rectification of faults and a high standard in every part.

Compare this state of affairs with that prevailing in a typical hardening shop some years ago.

Instead of a well-lit, well-ventilated, and comparatively clean shop, we find a dark, grimy shed, something like a miniature gasworks, unbearably hot and reeking with cremated ox-remains and fishy oil. Here a gang of men pound a dusty black mixture into iron pots round some of the articles that have just come from the machine shop or automatic shop; there another gang, equally grimy but more oily, wield tools that Tubal Cain may have used—their plant, crude furnaces, uncontrolled save by the unaided eye.

Not only were their tools and plant crude, their materials and labour were crude too. The labour employed was anything but skilled, and the case-hardening compositions savoured more of quack medicines than British pharmacopœia preparations. What little viewing was done threw little or no light on the causes of distortion, softness, or cracks. And this was the shop to whose tender mercies much of the machine shop output was handed over, there to be made or marred.

This then was the problem: to raise this outcast, isolated, and forlorn process of chemical industry to the dignity and standing of machine-shop practice; to investigate the materials it employs and throw light on their mode of action; to provide simple means of controlling the furnaces and of measuring the resultant hardness and resistance to shock; in a word, to do for the hardening shop what science and industry had already done for the machine shop.

An Improved Pyrometer.—We started out at the furnace end and decided to install pyrometers, but were soon met by the fact that an efficient pyrometric outfit for a battery of 13 muffles is an expensive thing, especially for an industry where the competition is so keen and the work so varied. Moreover, it threatened to cost something to keep it in working order; and on second thoughts it seemed very questionable whether thermo-electric and resistance pyrometers would be suitable for a system starting with a hot furnace full of cold work, or for ascertaining the temperature of an isolated article.

The Fèry instruments were then unknown, so the author started investigations at the Rudge-Whitworth Research Laboratory with the object of ascertaining the temperature of red-hot bodies from their colour. On examining the spectrum of a red-hot piece of steel it is found to elongate at both the red and violet ends and to increase in intensity all along as the temperature rises. This suggested the possibility of ascertaining the temperature of red-hot bodies by means of a direct vision spectroscope provided with a graduated scale (also used by Hempel), but it soon became evident that the difficulty of seeing just where the green ended precluded the possibility of anything approaching accuracy; and the extension of the red end was not sufficient for the purpose. Attempts were made, by screening off the brighter parts of the spectrum, to render the green or blue end more distinct, but it was found that the end point varied considerably with the same observer, and that many eyes cannot focus a sharp image on the retina when pure blue or green rays are transmitted.

Fig. 1 represents the spectra of red-hot steel in air, as seen by the author. The ordinates are estimated and the abscissæ measured.

Fig. 2 is a diagrammatic representation of two superposed spectra of red-hot steel, one representing a higher temperature than the other. The difference between the radiation at the two temperatures is D. If we could separate this difference from the radiation C common to both and measure it we should be in the best possible position for ascertaining the temperatures of red-hot bodies; much better than, for instance, by comparing the radiation C with C + D. This suggested that a solution just capable of absorbing all the coloured rays from steel at, say, 760° C., would transmit the excess intensity and extra wave-lengths of the rays emitted at 800° C. and the object would be visible. This was found to be as expected, and a long series of experiments was carried out to try and produce solutions and mixtures of solutions or emulsions, the absorption of which closely followed, both in range and intensity, the radiation curves for steel at different temperatures.

The Selection of Dyes.—Light from an acetylene flame was passed through the coloured solutions, organic and inorganic, and of various concentrations, then analysed by a spectroscope and the absorption spectra plotted; but the difficulty and endless work involved in determining the intensity (or degree of absorption) of the various colours made it commercially necessary to be content with an approximation to the required curve.

In conducting these experiments the author found that the eye is certainly more sensitive to small variations in the region of the dark red than in any other region, and this led to choosing dye solutions that transmitted an excess of red. A very feeble light, whatever the colour, appears grey or greyish green. This is said to be due to the rods of the retina being more sensitive to light than the cones. As soon as the intensity becomes sufficient the cones respond and give the impression of colour. When the observer is looking through one of these dye solutions the object is either invisible or very faintly visible, and it is found that the change from this grey or greyish green to dark red is far sharper than the change to any other colour tried—particularly the greenish blue at the end of the spectrum of steel at 700° to 1,000° C. It is found that, with solutions of this kind, a difference of temperature of 5° C. can be detected. That is to say, an excess of 5° C. sends sufficient radiations to the eye (D in Fig. 2) to

* Paper read before the Iron and Steel Institute, May, 1914.

render the object visible through the solution in question. Different observers are found to agree closely as to the temperature, showing that the error due to the different sensitiveness of different eyes is but little greater than the experimental error. With untrained observers the error may be 10° C.

Permanence of Dye Solutions. Having found a range of solutions capable of absorbing the rays emitted by red-hot steel at various temperatures, and at the same time suited to the peculiarities and conditions of the eye, the author proceeded to investigate the permanence of the various mixtures in the dark and under the action of light; also their behaviour in contact with retaining vessels such as glass and

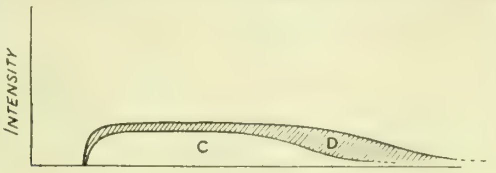


FIG. 2.

india-rubber. Some were found to decompose on keeping, some changed in colour, some precipitated; others were found to be soluble in glass. Some were found to withstand the action of light, in contact with glass and india-rubber, without any apparent change. Prof. Campion has independently confirmed the stability of some of the dyes chosen by the drastic test of exposing two pairs of cells to full sunlight for over a year. He found no deterioration in the solutions.

Calibration of Dye Solutions.—The chosen solutions were then calibrated by viewing the end of a steel cylinder heated in an electric furnace and taking the temperature of the steel at the moment it ceased to appear visibly red by means of a platinum platinum-rhodium thermo-couple pushed close up to the back of the cylinder end. To remove any possible error due to the temperature of the junction being perhaps not exactly the same as that of the visible end of the cylinder, the calibration of the couple was effected by melting a number of pure substances of known melting point on a minute ledge on the flat end. For temperatures above the scope of this arrangement the thermo-couple was dispensed with, and the melting of, for instance, nickel and platinum observed through the cells. This is, however, hardly the occasion to enter into details regarding the calibration and the precautions taken to ensure accuracy and some approximation to "black body" conditions.

Design and Method of Use.—In one of its forms the instrument, Fig. 3, has a stereoscope-like eye-shield to guard the eyes from extraneous light. Instead of two lenses there are two pairs of dye solutions well protected by caps, which also serve to keep the light out. This form is suitable when some particular temperature is required. For instance, the case-hardening temperature is now controlled by employing an instrument like this, with one pair of cells containing dye solution adjusted to 900° C. and the other to 925° C. If the pots are visible through the 900° pair and invisible through the 925° pair the temperature is considered correct. There is no need to remove the eyes while the pairs are changed; this is done by sliding the aluminium carrier to one side or the other. For reheating work, and for hardening tools, a single pair is all that is necessary. The hardening temperature is attained as soon as the work appears just visibly red. For double reheating two pairs are of course necessary, *e.g.*, 760° and 880° C. The cells can be interchanged and are readily detachable, so one instrument can be used to ascertain any temperature, provided the object be visibly red hot. The actual container is a glass tube less than 1in. long, with accurately fitting glass ends held together on rubber rings by two telescoping brass tubes. In form the cell is much like a short polarimeter tube. The caps on the aluminium slides are provided with springs to prevent the cells falling out.

In another form the instrument is adjustable and is either monocular or binocular. In these the dye solution is contained in expansible cells, and a range of absorptive powers obtained by altering the length of the column looked through. The temperature is given by a scale engraved on the tube, much like a micrometer is read. This form is perhaps not quite so accurate as the form with each cell specially made to one temperature. In this form the instrument is 3in. long by 1½in. diam. and is very handy. This method of determining temperature is a zero method and is therefore *cæteris paribus*, more accurate than one involving a comparison of colours. Furthermore, the critical point occurs when the eye is shaded from extraneous light, that is, when the pupil is dilated and the retina is in its most sensitive condition. In judging temperatures by the unaided eye errors are caused by (1) Extraneous light falling on the eye. (2) The difficulty of remembering close shades of colour. (3) Errors of judgment in comparing the image of the colour observed with a series of mental images of colours previously seen.

All these chances of error are eliminated by an instrument of this kind. No extraneous light falls on the eyes and no recollection is required; the hardener has simply to look through, wait about half a minute until his eyes have become accustomed to the darkness, and then see whether the object is visible as a dark red patch or invisible. Hardeners seem to prefer to use their eyes for telling the temperature, and these instruments provide pyrometric equivalents for limit gauges and screw micrometers, and at the same time screen the eyes from the glare and heat of the furnace.

The readings are admittedly dependent on the sensitiveness of the eye; if this varies from person to person the temperature readings will vary accordingly, being lower the more sensitive the eye. As already stated, these variations do not affect the accuracy momentously, and from actual experiments carried out with this and with another optical pyrometer working under very similar conditions the author feels compelled to believe that the variation in sensitiveness, under the actual working conditions of these instruments, is not nearly so great as might be expected.

If the object be a large one, it is advisable to interpose a perforated screen between it and the instrument. One way to make an observation is to adjust the instrument to a lower temperature than that expected, and then, by sliding darker cells into position, or by unscrewing (if the adjustable form), darken the image until it just ceases to appear coloured. The temperatures engraved on the cell or the body of the instru-

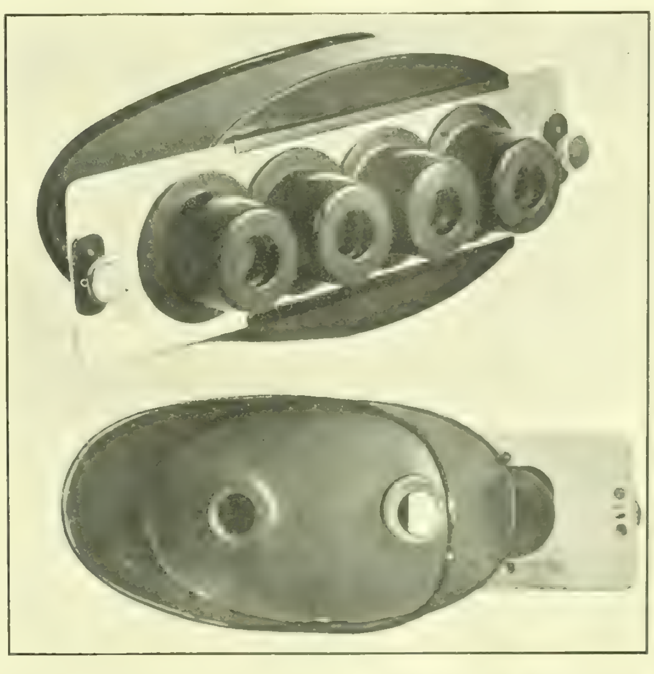


FIG. 3.—PYROMETER FOR OBSERVING TWO TEMPERATURES. OUTSIDE AND INSIDE VIEWS.

ment will then indicate the temperature of the hot body, provided that the conditions of the test are as nearly "black body" as those obtaining when the calibration was effected. Fortunately red-hot iron and steel surfaces have an emissivity of nearly unity, so the error is not large, and can generally be neglected for industrial purposes. Furthermore, any error from this source will not prevent the instrument giving comparative readings under similar conditions, which is all that is necessary in repetition work.

These instruments have been applied with satisfactory results to the heat treatment of steel, carburising, reheating, annealing, and hardening tools of all kinds. One has out-

lasted two thermo electric pyrometers, and it is the author's opinion that a pyrometer which indicates its own temperature may convey some idea of the temperature of the work, but will never be the hardener's friend to the same extent as one of the forms of optical pyrometer which can be focussed on the article itself.

Case-hardening Compositions.— Having provided a simple and effective device for ascertaining the temperature of red-hot bodies, the author set about investigating case-hardening compositions — their nature, mode of action, and effect. Obviously for carburising to occur (1) the heat must first penetrate to the steel and raise it to the gamma condition; it must (2) liberate and maintain a supply of the carburising ingredients; (3) the peripheral layers of the steel must combine with (or dissolve) these ingredients; and (4) the carbide must diffuse from the periphery inwards.

The composition of case-hardening materials varies very widely. The following table shows the range of variation in 17 commercial "compositions" tested:—

TABLE I.

	Per Cent.
Moisture	2·68 to 26·17
Oil	0·17 „ 20·76
Carbon (organic)	6·7 „ 54·19
Calcium phosphate	0·32 „ 74·75
Calcium carbonate	1·2 „ 11·57
Barium carbonate	nil „ 42·0
Zinc oxide	nil „ 14·5
Silica	nil „ 8·14
Sulphates (SO_3)	trace „ 3·45
Sodium chloride	nil „ 7·88
Sodium carbonate	nil „ 40·0
Sulphides (S)	nil „ 2·8

When these experiments were commenced the mixture of barium carbonate, 40 per cent., and charcoal, 60 per cent., suggested by Guillet had not been put forward, and it was usual to use case-hardening compositions once only or perhaps twice.

Another drawback experienced in commercial operation, for instance, with pots 10in. high by 10in. diam., was the difference in the depth of penetration near the middle and the outside of the pot. Some compositions showed as much as 150° C. difference in temperature between the inside and the outside. The author accordingly set out to improve: (1) Permanence, and to obviate loss of activity and consequent wastefulness. (2) Permeability to heat, and to obviate unequal heating and casing.

Permanence. — The supposition that this loss of carburising power was due to loss of nitrogenous constituents was confirmed by the author's early experiments. Spent hardening mixture may contain 12 per cent. organic carbon (total carbon, less carbon in carbonates), and yet, under similar conditions, have far less carburising power than fresh material containing less carbon. Such spent mixture gives indication of only traces of nitrogen. Two similar compositions, one having a much greater carburising power than the other, gave the following results by the Kjeldahl test:—

Composition.	Nitrogen per cent.
Good	2·72, 2·60
Bad	0·51, 0·47

Indirect evidence of the influence of gases (possibly nitrogenous) evolved from the mixture is afforded by the results of the comparative tests recorded in Table II., which show

TABLE II.

Composition: 50 per cent. bone black, 25 per cent. bone dust, 25 per cent. oil

Experiment	Without Coal-gas	With stream of Coal-gas through mixture	
No. 1	Case 0·0374in. Saturated.	Case 0·0296in. Unsaturated	Slow stream.
No. 2	Case 0·045in. Saturated.	Case 0·038in. Unsaturated	Slow stream.
No. 3	Case 0·043in. Saturated.	Case 0·024in. Unsaturated	Faster stream.

Time, 2 hours. Temperature, 900°-925° C. Rods ¼in. round.

that it is possible to carry off the carburising gases by a current of coal gas in much the same way that oil is removed by steam distillation. On the other hand, heating in gases which contain no nitrogen compounds may carburise mild steel, as indicated in Table III.

TABLE III.—*Case-hardening in Gases.*

Temperature about 880° C. Rods ¼in. round.

Gas.	Results.	Case.
Acetylene pure. ¾ hour.	Acetylene completely decomposed. Carbon deposited on specimen.	0·0064in. thick. Unsaturated.
Acetylene 1 vol.; Coal gas 3 vols. 1 hour.	Specimen coated with carbon.	0·0017in. thick. Unsaturated.
Acetylene 1 vol.; Coal gas 12 vols. 1 hour.	.. . ..	On one side 0·0147in. thick. Unsaturated.
Acetylene 1 vol.; Coal-gas 20 vols. 1 hour.	. . ..	On one side 0·0117in. thick. Unsaturated.
Acetylene 1 vol.; Coal-gas 40 vols. 1 hour.	. .. ..	Only where carbon deposited 0·0117in. thick. Unsaturated.
Coal gas bubbled through carbon disulphide. 1 hour.	.. .. ..	No case. Layer of sulphide formed.

Experiments extending over a considerable time and range of compositions have confirmed the following supposition: (1) the depth of case depends chiefly on the temperature the steel attains and the duration of the hot condition. On these factors depend the rate and extent of the diffusion of the carbon or carbide. (2) The concentration of the carbon in the case depends chiefly on the "activity" of the mixture, or rate at which it or its products part with carbon to the steel. The concentration of carbon in the surface layers may increase or decrease with temperature, but usually increases as the temperature rises and with the time. (3) The duration of the hot condition for a given time of heating depends chiefly upon the permeability to heat of the case-hardening composition.

Exhaustion Tests. — Comparative depth of penetration has been the subject of a number of investigations, but is so much dependent on factors other than the case-hardening composition that the author has sought for some other test. The one finally adopted is to take a known volume of the composition and ascertain the volume of the "case" that can be got from it without replenishing.

The ratio total volume of case: initial volume of case-hardening material, affords a good indication of the efficiency of the composition, and is not so dependent as a single penetration measurement on other factors such as size of pot, number and size of the articles it contains, loss of heat from furnace walls when the pot is introduced, &c. These "exhaustion" tests have been made in pots of various sizes, but usually in nickel-plated steel tubes 7in. long by 1½in. diam., and heated in a laboratory muffle for 1½ to 2 hours, starting with the muffle hot. A fresh piece of mild steel, such as ⅜in. round, is used for each heating, and the period is that required to give, at 900° to 930° C., a case deep enough for commercial use, viz., 0·015in. to 0·065in. Transverse sections are examined microscopically, and the mixture is considered to be exhausted when ferrite bands can be seen between the pearlite grains at the periphery, that is, when the case is unsaturated. With most commercial case-hardening mixtures it is usual to find that the periphery is unsaturated after six or seven heatings of two hours each. The results of testing some experimental mixings are to be found in Table IV.

An Improved Case-hardening Composition.—The last mixture in Table IV. is eminently suitable on the score of permanence, and can be used over and over again indefinitely, provided that the inevitable waste involved in commercial usage is made up from time to time with fresh composition and that the ingredients are well incorporated and in the proper proportions. The author was led to combining charcoal with potassium carbonate, sodium carbonate, and potassium hydrate by the results of tests on charcoal. This rapidly loses its carburising power. It also contains traces of potassium carbonate, which would react with red-hot charcoal and produce carbon monoxide. Incorporating a little potassium carbonate with exhausted charcoal is found to restore at once

its carburising power and make it give up its carbon more readily than the original charcoal. The same is true when potassium hydrate or sodium carbonate is incorporated.

TABLE IV.

Mixture.	Ratio Total Volume of Case Initial Volume of Mixture.
Anthracite 75 per cent., oil 25 per Cent.	nil.
Anthracite 95 per cent., potassium carbonate 5 per cent.	0·0042
Coke soaked in 10 per cent. aqueous solution of potassium hydrate	0·0048
Anthracite soaked in 10 per cent. aqueous solution of potassium hydrate	0·0061
Anthracite 90 per cent., calcium cyanamide 10 per cent.	0·0109
Crushed bone	0·0122
Anthracite 90 per cent., bone black 10 per cent.	0·0138
Wood charcoal	0·0140
Charcoal 90 per cent., crushed bone 10 per cent.	0·0262
Wood charcoal 90 per cent., calcium cyanamide 10 per cent.	0·0331
Wood charcoal 90 per cent., crushed bone 10 per cent.	0·0368
Bone black	0·0405
Leather charcoal	0·0405
Wood charcoal 90 per cent., bone black 10 per cent.	0·0451
Charcoal soaked in 20 per cent., caustic potash 90 per cent., crushed bone 10 per cent.	0·058
Wood charcoal impregnated with soda ash	0·116

That the carburising power of such mixtures is due to nitrogenous compounds or cyanides is unlikely. Charcoal soaked in a 5 per cent. aqueous solution of sodium carbonate and dried, after three heatings contained:—

	Per cent.
Nitrogen	0·12 (Kjeldahl)
Cyanides	nil

Yet this gave a saturated case even after the tenth, eleventh, and twelfth heatings. The author has not fully investigated the nature of the reaction, but comparative tests show that charcoal in an atmosphere of carbonic oxide does not give quite the same result as the charcoal and alkali mixture. Under similar conditions charcoal alone gave an unsaturated case; charcoal and carbon monoxide gave a more saturated but still unsaturated case; and the charcoal and alkali gave a saturated case.

(*To be continued.*)

PREVENTION OF ACCIDENTS IN FOUNDRIES.

IN accordance with the recommendations of the conference between employers, operatives, and inspectors concerning safeguards for the prevention of accidents in iron foundries, the Secretary of State proposes to make regulations under Section 79 of the Factory and Workshop Act, 1901, to carry out the agreements at which they arrived. A draft of the proposed regulations is appended. Any objection with respect to the draft regulations must be sent to the Secretary of State not later than July 8th, 1914. Every such objection must be in writing, and must state (*a*) the draft regulations or portions of draft regulations objected to; (*b*) the specific grounds of objection; and (*c*) the omissions, additions, or modifications asked for.

Regulations dated ——, 1914, made by the Sercetary of State under Section 79 of the Factory and Workshop Act, 1901 (1 Edw. 7, c. 22.) to apply to all factories and workshops or parts thereof in which the casting of iron or steel is carried on.

In pursuance of Section 79 of the Factory and Workshop Act, 1901, I hereby make the following regulations and direct that they shall apply to all factories and workshops or parts thereof in which the casting of iron or steel is carried on.

Provided that these regulations shall not apply to the casting of pig iron from blastfurnaces, or to the casting of steel ingots.

These regulations shall come into force on ——, 1914.

** Definition*

In these regulations:

Moulding shop includes that part of the factory or workshop in which the cupola is situated, and all parts in which molten metal is caught, conveyed, or poured.

Duties.

It shall be the duty of the occupier to observe Part I. of these regulations.

It shall be the duty of every person employed to observe Part II. of these regulations.

PART I.—*Duties of Occupiers.*

1. Where iron plates are used in a *moulding shop*, either as gangways or under furnace spouts, they shall be kept constantly dry.

2. Where molten metal is carried by hand between rows of moulds or boxes, a clear passage way, not less than 18in. in width, shall be provided and maintained between such rows.

3. Where molten metal is conveyed across an open space, a clear passage way, dry and covered where practicable, shall be provided and maintained between the cupola and the place where casting is done. Provided, however, that it shall not be deemed to be practicable to erect a covered way, if to do so would interfere with operations necessarily carried on in the intervening space.

4. No person under 16 years of age shall convey or assist in conveying molten metal.

5. Requisites for treating wounds and burns shall be kept at hand and be placed in charge of a responsible person.

6.—(*a*) All chains used for lifting or moving any material shall have been tested and shall be periodically examined. They shall be effectually softened by annealing or firing when necessary; and half-inch or smaller chains in general use shall be re-annealed or fired once at least within every six months.

Chains to which new links or rings have been added shall not be used until they have been re-tested.

(*b*) A register shall be kept on the premises, containing the distinctive mark or number of each chain, the date of each test and re-test, the test load, the safe working load, and the dates of annealing or firing.

7. In any part of a *moulding shop* where molten metal is caught, conveyed, or poured, adequate protection for the feet shall be provided and maintained in proper order and repair for the use of all persons employed in that part. Such protection shall consist either of boots fitting closely above the ankles and constructed without lace holes or other openings in which molten metal can lodge, or of spats, flaps, or other appliances fitting closely above the ankles and covering all such openings in the boot, shoe, or clog worn by the person employed.

PART II.—*Duties of Persons Employed.*

8. Every person employed in any part of a *moulding shop* where molten metal is caught, conveyed, or poured, shall, while any of these operations is going on, constantly wear the protection for the feet specified in regulation 7.

* The term "*moulding shop*" to which a defined meaning is given is printed throughout in italics.

Bursting of a Gas Cylinder.—Through the bursting of a gas cylinder used in connection with apparatus for taking burrs off tramway lines, a London County Council employé was seriously injured on the 12th inst. in the Hackney Road, London.

Institute of Metals.—Portsmouth has been selected as the place of meeting for the autumn conference of the Institute of Metals. The conference, which will be presided over by Engineer Vice-Admiral Sir Henry J. Oram, K.C.B., F.R.S., the president of the Institute of Metals, will be held on Thursday, September 10th, and Friday, September 11th, in the Municipal College, a number of important papers being read each morning. In the afternoon of September 10th a visit will be paid to Portsmouth Dockyard, and there will be a dinner in the evening. On September 11th the afternoon function will consist of a luncheon at the Cowes works of Messrs. J. Samuel White & Co., the works afterwards being visited.

CONTROLLING DEVICES FOR LOCOMOTIVE CYLINDERS.

THE accompanying illustrations show a by-pass controlling device especially applicable to the cylinders of locomotives, the invention of H. A. Stenning and Schmidt's Superheating Company (1910), Ltd., 28, Victoria Street, London, S.W. Fig. 1 shows the general arrangement as applied to the cylinders of a locomotive, while Fig. 2 shows a cross-section through the by-pass controlling device, which is connected by means of pipes A and B to the front and back cylinder covers, respectively. The device is arranged so that the passages F and G leading to the connections A and B are disposed one above the other, communication between these passages being effected by the operation of a valve, the working face D of which co-acts with a valve seat E. The valve spindle carries at its upper end a circular enlargement H, which acts as a piston. The enlarged end of the valve is disposed in a chamber K, the top of which is placed in communication with the steam chest or main steam pipe by the pipe connection L. The under side of the enlargement is connected to a supply of steam independently of the main steam pipe, and preferably to the boiler steam cock by the pipe M. In some cases the bottom of the controlling device is provided with an outlet to the atmosphere, and is controlled by a relief valve N, attached loosely to a short spindle.

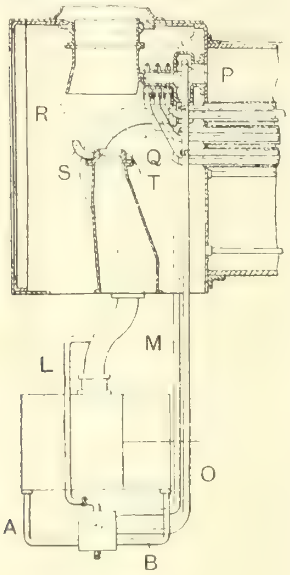


FIG. 1.

The operation of the device is as follows: When the regulator is in such a position that steam is being admitted to the engine cylinders, the connection L on the top of the device admits steam from the main steam pipe or the valve chest to the upper side of the piston H. Steam from the boiler will also be admitted below the piston, directly from the boiler cock, by the pipe M, but as the area beneath the piston is less than the area above the same by the area of the spindle, the valve face D is forced upon its seat, and no connection is made between the front and back ends of the cylinder by means of the by-pass. If, however, the regulator is closed, the steam pressure on the upper side of the piston is withdrawn, and steam from the boiler cock entering below the piston by the pipe M will force the piston upwards, lifting the valve face D off its seat, and allowing communication to be effected between the front and back ends of the cylinder by means of the by-pass, thus equalising the pressure on the piston in the engine cylinder.

In those cases in which a relief valve N is provided for the purpose of placing the by-pass in communication with the atmosphere, the operation of the valve for effecting communication between the front and back ends of the cylinder will simultaneously open the relief valve and connect the by-pass with the atmosphere. Further, in the event of water accumulating in the cylinders, the engine piston as it moves towards the end of its stroke exerts pressure on the water, and when the pressure is sufficient, will force the valve up against the steam pressure on its enlarged end, and open the relief valve communicating with the atmosphere. The water in the cylinder will thus automatically escape.

The device is especially suitable when used in conjunction with locomotives provided with superheaters, in which a small supply of steam is allowed to circulate through the superheater elements when the main supply of steam to the engine cylinders is cut off. In this case, as shown in Fig. 1, connection is made by means of a pipe O between the space beneath the piston of the controlling device and the saturated chamber P of the superheater, so that the steam from the boiler cock, as well as operating on the piston H of the controlling device, may also pass to the superheater elements and prevent overheating of the same when the regulator is closed. The steam, after circulating through the superheater elements, passes through the steam chest and cylinders, and finally to the atmosphere by the relief valve N. Each cylinder is provided with the controlling device, the connection being such that all the controlling devices are operated simultaneously. The connection to the saturated chamber of the superheater may be made from only one or all of the controlling devices as desired.

By means of the above-described arrangement the by-pass valve is held positively in an open position by the steam from the boiler cock acting below the piston H, so that when the engine is stationary and steam is passed through the superheater tubes to prevent them overheating, pressure cannot

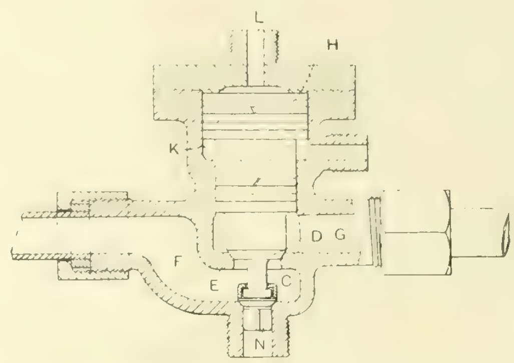


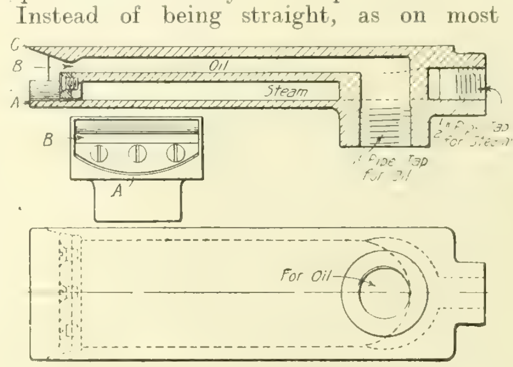
FIG. 2.

accumulate in the engine cylinders, and consequently there will be no danger of creeping of the engine taking place.

In some cases the steam passing through the pipe M is utilised to operate the blower by leading a branch pipe Q to a cock R, and thence by means of a pipe S to the blower T. By employing this arrangement it will be necessary for the boiler cock to be opened before the blower can be put into operation. As the steam from the boiler cock operates the bypass control valve, and also passes through the superheater tubes, the blower cannot be put into operation with the regulator in the closed position without the by-pass being opened and steam being circulated through the superheater tubes. The danger of overheating the superheater tubes when getting up steam with the blower in operation is thus avoided.

OIL BURNER FOR LOCOMOTIVES.

A DESIGN of oil burner which is being applied to 20 locomotives on the Esquimalt and Naniamo Railway, Vancouver Island, B.C., is shown in the accompanying sectional views reproduced from the "Railway Review." The distinguishing feature of this burner is noted in the form of lip over which the steam passes and whereby the shape of the flame is determined. Instead of being straight, as on most burners



OIL BURNER FOR LOCOMOTIVE BOILERS.

hitherto tried, the orifice in this case takes the form of an arc of a circle which so shapes the flame that, in effect, a greater area is made available for radiation against the side sheets of the firebox. The extent to which this modification is beneficial is, our contemporary states, indicated by the fact that in a recent trial on the lines of the Canadian Pacific Railway this burner evaporated 10 per cent. more water per gallon of fuel and consumed 10 per cent. less oil per 1,000 ton miles than did the straight lipped burner against which it was tried.

DESIGN AND OPERATION OF MODERN BOILER-HOUSE PLANT.*

BY S. E. FEDDEN, CHIEF ELECTRICAL ENGINEER OF THE CORPORATION OF SHEFFIELD.

THE main points to consider in the laying down of a steam driven power station are: (1) Adequate supply of water for condensing purposes. (2) Ample facilities for dealing with ashes. (3) Good accommodation for getting in and storing coal.

There is no need to deal with No. 1, as it is beyond the province of this paper. No. 2, however, is becoming a very serious source of expense and concern in large cities, because of the difficulty of obtaining tips within a reasonable distance of the station. In Sheffield the cost of carting has increased no less than 40 per cent. within the last few years. This increased expense can quite appreciably increase the cost per unit, and when one arrives at a certain point in this cost of removing ashes it is necessary to take into consideration whether it is not worth while to buy a high-priced coal with a minimum percentage of ash, say, 4 or 5 per cent., instead of the cheaper class of engine slack with its 10 per cent. to 15 per cent. of ash. The author has lately gone to considerable expenditure to deal with ashes. A lease of a valley adjacent to the power house has been obtained and a steel bridge erected for guard purposes over the main line of the railway. A ropeway 200 yards long has been installed, capable of dealing with 20 tons of ashes per hour. This method of dealing with the ashes was arrived at after investigating the undermentioned alternative schemes, which worked out as follows:—

Disposal of Ashes.	s.	d.	
Railway	2	9½	per ton
Cartage	1	11	,,
Ropeway	1	3	,,

No. 3. Dealing with the facilities for getting in coal, it is advantageous to choose a site having a high level siding, so that the trucks come in straight off the railway over the top of the bunkers, thereby doing away with the expense of installing and running coal conveyers. This should be self evident, as it costs much less to elevate the 5 per cent. to 10 per cent. of ashes, than to handle the full quantity of coal, in addition to the probability of having to lift the ashes again. Neepsend power house is arranged on this plan. The capital cost per kilowatt for the first section of the station is below £10, including the cost of land and sidings.

It will be seen from the accompanying illustrations that although the turbines are widely spaced, the boilers have to be cramped, in order to obtain the necessary amount of steam. The original plan of boilers in line with the engine room had to be amended, and the boilers placed in a transept running out of the original boiler-house. The present equipment of the boiler-house consists of 11 water-tube boilers of the following capacities, three more boilers being under construction to be erected for next winter's load.

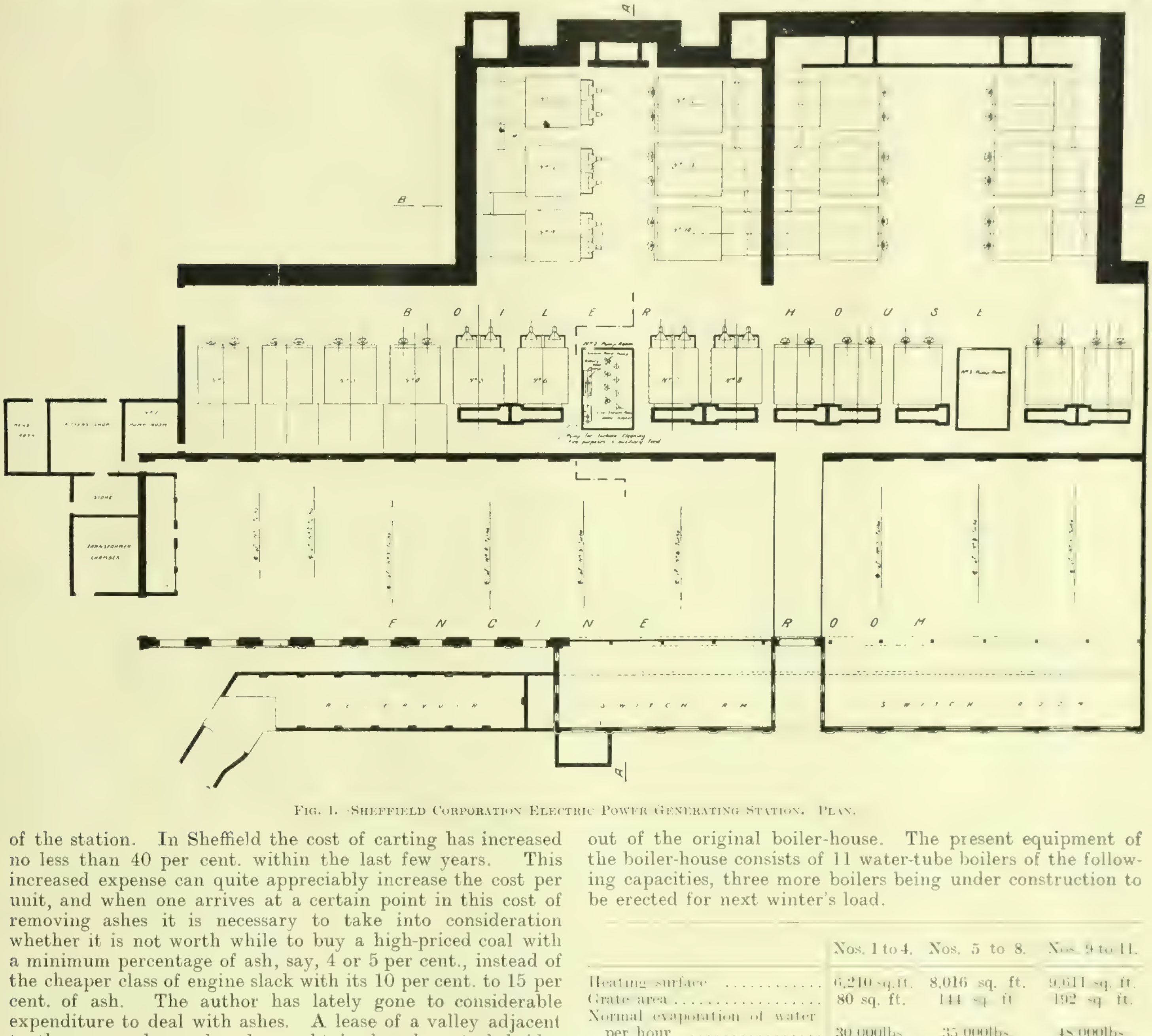


FIG. 1.—SHEFFIELD CORPORATION ELECTRIC POWER GENERATING STATION. PLAN.

	Nos. 1 to 4.	Nos. 5 to 8.	Nos. 9 to 11.
Heating surface	6,210 sq. ft.	8,016 sq. ft.	9,611 sq. ft.
Grate area	80 sq. ft.	144 sq. ft.	192 sq. ft.
Normal evaporation of water per hour	30,000lbs.	35,000lbs.	48,000lbs.
Steam drums	3 of 3′ 6″ diam.	3 of 4′ 0″ diam.	3 of 4′ 0″ diam.
Mud drums	2 of 3′ 0″ diam.	2 of 3′ 0″ diam.	2 of 3′ 0″ diam.
Number of tubes	432	540	648
Stokers	Bennis	Chain grate and underfeed	Chain grate

The boiler-house is provided with two pump rooms. No. 1 contains: Four feed pumps of the long stroke vertical compound double-acting type, three having a capacity of 3,000 galls. per hour, and the fourth 10,000 galls. per hour. Three live steam feed-water heaters, capable of raising the temperature of the feed water from 85° to 135° Fah. No. 2 contains: Four feed pumps of a similar type, with a capacity

* Abstract of paper presented at the annual convention of the Incorporated Municipal Electrical Association, Birmingham, June, 1914.

of 10,000 galls. each per hour. One rotary feed pump, motor driven, with a capacity of 20,000 galls. per hour. One motor-driven centrifugal pump, with a capacity of 10,000 galls. per hour. The duties of this pump are of a three-fold nature: (1) In the event of the town water supply being cut off, water can be pumped from the river direct to the overhead feed tank. (2) It can be connected to the existing water service mains where the town supply is not available to provide a supply of water for fire purposes. (3) Economy is effected by using the river water in place of town water for cleaning out the boilers. Five live steam feed-water heaters.

An overhead tank is fixed above each pump-room, the capacity for No. 1 pump-room being 20,000 galls., and No. 2 pump-room 25,000 galls. The exhaust steam from each steam feed pump is led to the overhead feed-water tank, the exhaust pipe having a silencer fitted. It is, however, essential that great care should be exercised to prevent oil getting into the economisers and boilers.

The whole of the steam piping is wrought steel lap welded, with cast-steel tee pieces. The valves and by-passes are also of cast steel suitable for use with superheated steam. The steam pipe is 10in. and 12in. diam. single main, and runs the whole length of the boiler-house. The turbines and boilers are connected to the main steam pipe by single connections, and the steam of the feed pumps only having a ring main. The water mains are of cast iron 6in. diam. with flanges bracketed. There are two main feed pipes, hot and cold, running the whole length of the boiler-house, and these mains are interconnected by valves so that if a fracture occurs either main can be put into commission. Further, the pipes are arranged in standard lengths as far as possible, so that a fractured pipe can be readily replaced. Expansion pipes are provided by means of copper bends in both mains, and additional precautions are made by having copper bends in each branch connection to the boilers and economisers. The steam and feed-water mains are carried on roller supports whenever possible, and sling supports in other positions.

Provision is made for a three weeks' supply of coal opposite each boiler on the siding level, and each boiler has a shoot holding about 100 tons of coal, which feeds by gravity into the mechanical stoker hopper. At the top of these shoots, and, in fact, between all the railway lines over the bunkers, is provided a steel grid to prevent any large lumps getting through. Bottom-emptying trucks are brought directly over these shoots, and, with the exception of trimming from the extreme corners of the trucks, the major portion of the coal is never handled from the time of putting it in the trucks at the colliery until it is taken hold of by the mechanical stokers. The shoots are fitted with measuring chambers and indicating gear, and the coal is led through breeches pieces to the stoker hoppers.

The next important item in regard to a boiler-house is the water supply. If good water is not available it should be treated at any reasonable cost before it goes into the economiser or boiler, and if it is very cold, say, below 80° Fah., the temperature should be increased to 110° Fah., even though live steam feed-water heaters are installed to effect this. Many engineers argue that warming water by live steam is economical and saves coal, but that has never been proved to the author, although he concedes this, that any loss incurred by heating the feed water by live steam is well and amply repaid in the saving of repairs to the economiser and boiler tubes, and therefore is a saving of capital expenditure which would otherwise be required for extra economisers and boilers as spares. The author supports this contention from actual experience.

The live steam feed-water heaters which the author has had in use for some years have been those fitted with a patent indented tube. This is made by taking a plain round tube and indenting it in a regular manner at right angles, so that fluid passing through the tube is thoroughly broken up and diverted into contact with a large amount of impinging surface. It is claimed that a tube so indented has increased the heat transmitting properties in excess of an ordinary plain round tube, as the breaking up of the centre core of the tube increases the velocity of the steam through it and keeps the steam in active contact with the copper. I may say that I have had some years' satisfactory use of live steam feed-water heaters fitted with this patent tube.

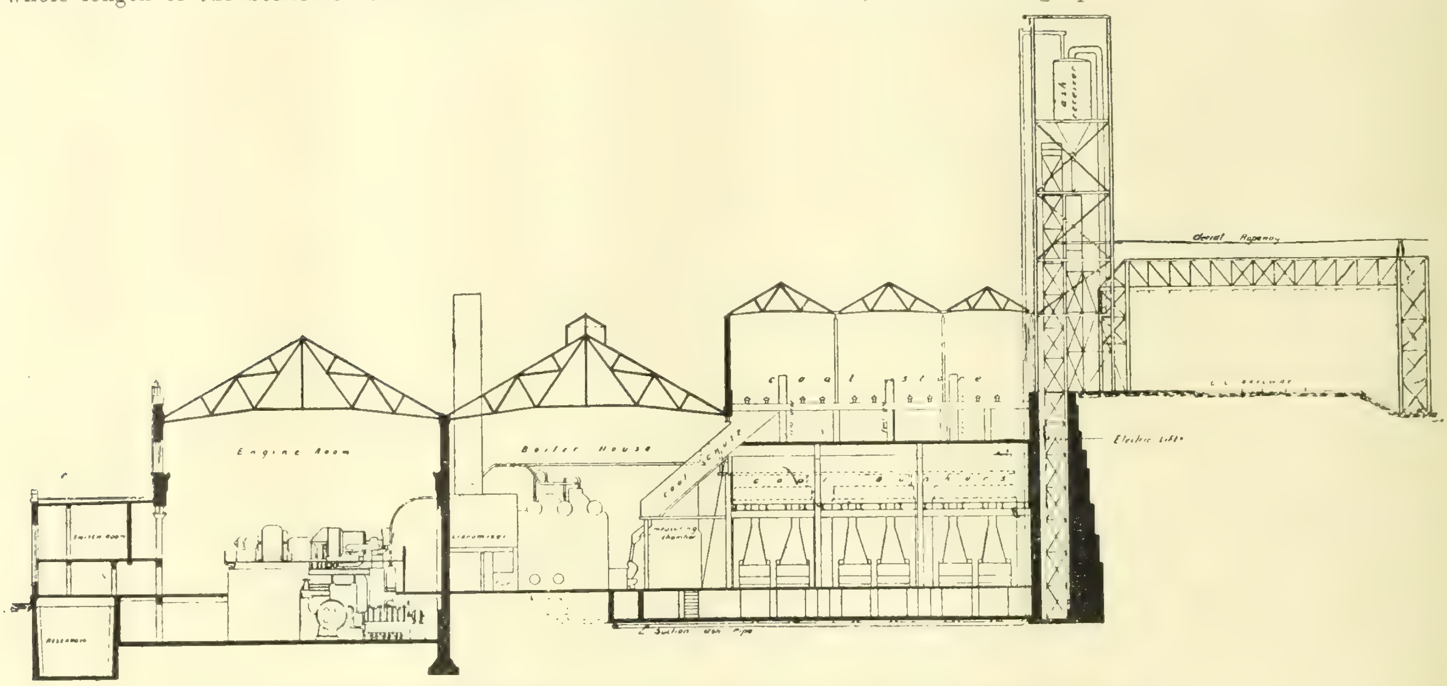


FIG. 2.—SHEFFIELD CORPORATION ELECTRIC POWER GENERATING STATION. SECTION ON LINE A -A OF FIG. 1.

In dealing with the boiler-house itself, this should be made roomy, high, well ventilated, and as light as possible, and ample room should be provided both under the stokers and in front of the boilers. Further, the ash disposal arrangements should be such that the ashes can be lifted from two or three points in the ashes trench, and whether rails, trucks, elevator, or suction plant be employed, it is well not to be absolutely dependent on any one of these, but openings should be left in the boiler-house floor covered with plates, so that the ashes can in an emergency be taken away by carts driven into the boiler-house firing level or underneath if the lay-out will allow. At Neepsend the ashes are elevated to an overhead hopper and taken away to the tip ground by a bucket ropeway.

A suction ash plant is about to be put in for all new boilers and eventually for the old ones by which the author expects to save considerable labour, and also do away with much dirt and dust besides causing the atmosphere in the ashes trench to be less vitiated by the fumes, also to clean soot from soot chambers and economisers, thus reducing the amount of manual labour. The system of suction plant has been fully described within the last year or two, and I feel there is no need for a further description. However, manufacturers' opinions seem to differ very considerably as to the means of conveying the ashes and gritty matter by pipes to the receiv-

ing chamber. Some recommend a blower of the Roots type, while others recommend a continuous suction by means of a motor-driven fan. A similar difference of opinion appears to exist as to the advisability of introducing a ventilating plant into the suction circuit so as to exclude the fine particles of dust from the veins or slides which would be quickly scored away.

As to the type of boiler to be used very little can be said. Circumstances force careful engineers to use practically one of five or six types in this country, and of course these are of the water-tube type. There is very little to choose between them; they all want good water. The author thinks that from experience the boilers made in this country are of first-class design and workmanship, and with due care the cost of maintenance should not be heavy. The author is in favour of the vertical tube boiler, having experienced very good results from this type, but other engineers have no doubt obtained equally good results from the horizontal tubed boilers.

The aim of all engineers is to get the maximum evaporation out of the smallest floor space. This means a large grate area and the burning of as much coal as possible per square

At 25lbs. of coal (rough engine slack) per square foot grate area.
Evaporation per square foot of heating surface 5·25lbs.
In going gases to economiser . . . 450° Fah.
Out going gases from economiser . . . 300° Fah.

though it is quite possible to burn the same class of coal up to 30lbs. per square foot of grate area with good economy.

With regard to the rating of the water tube boilers it is a matter of common knowledge that the rate of evaporation in the neighbourhood of the furnace is very high compared with other parts of the boiler. As the rate of combustion increases so does the rate of evaporation with the same size of boiler. The author has noticed that manufacturers have put forward for different capacities similar sizes of boilers, but with stokers having a larger grate area so that some standard as to rating should be adopted. The standard adopted by the electric supply department at Sheffield is that the normal evaporation should be obtained by burning 25lbs. per square foot of grate area with a chain grate stoker burning engine slack.

The author has lately installed some 8ft., Class E. underfeed stokers to two water-tube boilers fitted with both forced and induced draught. The boilers were specified to evaporate

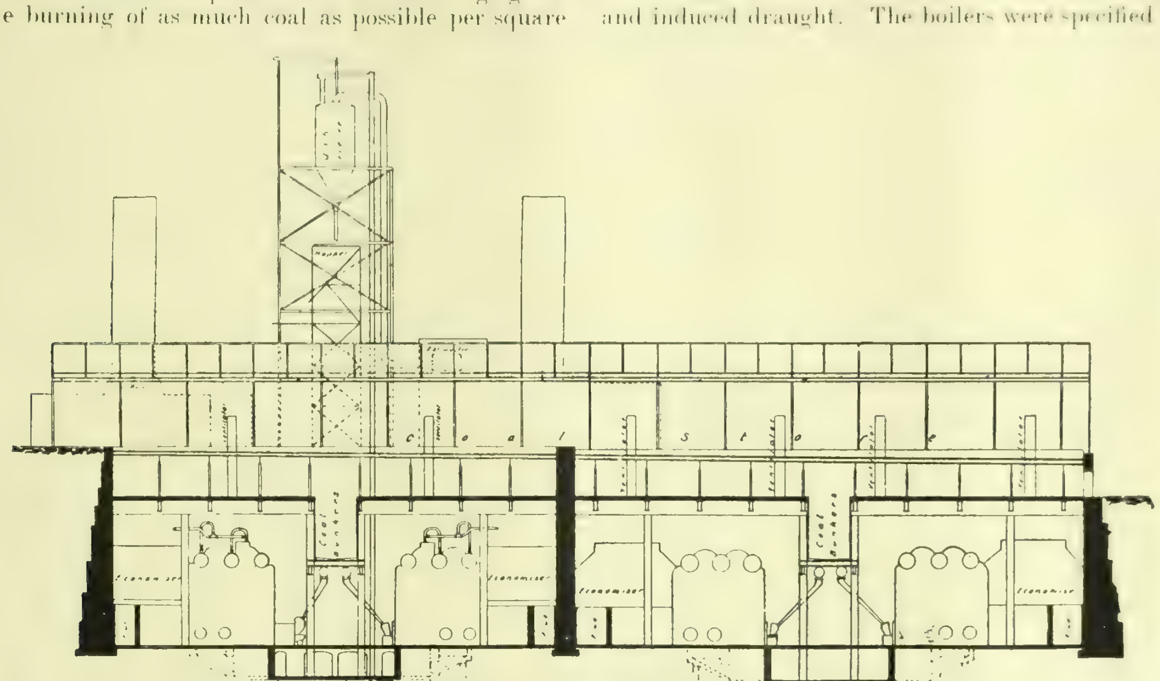


FIG. 3.—SHEFFIELD CORPORATION ELECTRIC POWER GENERATING STATION. SECTION ON LINE B–B OF FIG. 1.

foot of grate area. There is, of course, an economic limit to this high rate of combustion both as regards efficiency and maintenance, but it is very comforting to feel that boilers can be pushed to 40 or 50 per cent. above their normal working load in case of emergency. In the event of a very high rate of combustion becoming general and proving itself satisfactory, there will have to be a re-designing of the boiler combination by the adoption of larger economisers, superheaters, flues, feed pipes, steam pipes, fans, coal bunkers, ash disposal arrangements.

However, the size of the boiler and the amount of steam required per square foot of ground is governed to a certain extent by circumstances, and the money available for the installation, and engineers must consider each case on its merits. If land is scarce an economiser raised above the outlet damper of the boiler has much to recommend it, as of course there is then no check to the natural flow of the gases. As an offset to this, however, additional expenditure is incurred in steelwork to support the economiser, and also in the building of a high boiler-house, and it may cause a considerable reduction in the capacity of the overhead coal bunkers. The author considers with his present knowledge that the best over-all efficiency and least maintenance cost is obtained by running the following combination:—

Water-tube boilers.
Economiser.
Chain-grate stokers.
Induced fan draughts.

35,000lbs. of steam each from and at 212° Fah. The combination is as follows:—

Water-tube boilers.
Economisers.
Underfeed stokers.
Induced-draught fan, H.P. on load 55, giving 1·3in. draught.
Forced-draught fan, H.P. on load 30, giving 2in. draught.
Normal coal per square foot of grate area, 33·5lbs.
Evaporation per square foot of heating surface, 5·25.
In-going gases to economiser, 518° Fah.
Out-going gases from economiser, 290° Fah.

The results are: Burning up to 47lbs. of coal per square foot of grate area under the above working conditions the boiler evaporated 58,000lbs. of water per hour from and at 212° Fah., but the heat of the brickwork was so intense after the first hour's run that the rate of burning was reduced to 38lbs. per square foot of grate area. The superheater was not designed to deal with this large amount of steam, the temperature being reduced from 150 under normal conditions to 110° Fah. The author thinks that this combination has a great future before it and its limit will be determined by the ability of the brickwork, &c., to withstand the intense heat generated in the furnace with the above conditions.

Another important consideration is the form of draught to be employed, natural, induced, Pratt's, or forced. There are many claims that the natural draught system is the right

and most economical one, but it lacks flexibility, and makes it so dependent on atmospheric conditions, good coal, &c., and many instances are recorded where generating stations have been started with high brick chimneys, where at a later date fans have had to be added to secure the necessary flexibility and draught.

The author is a believer in mechanical induced draught, and when considering the problem strongly advocates that care should be exercised to install a fan or fans capable of dealing with the worst atmospheric conditions and of dealing with sufficient gases for the maximum possible overload of the plant. Regarding the hot versus cold air systems of induced draught, it would appear that the latter should be the more economical, owing to the smaller power said to be required to deal with the lesser volume. The author investigated this matter some three or four years ago, but could not satisfy himself that there was any very great benefit to be derived, besides which the cold air injector was expensive to manufacture and renew.

A decision with regard to the type of mechanical stokers is difficult to arrive at. The ideal stoker should be able to deal with clean nuts or smudge, should be able to get to full duty from banked fires in the shortest possible time, should be capable of doing 50 per cent. above its normal duty for short periods in case of emergency, should consume all combustible matter fed on to it with the most efficient percentage of CO_2, should be smokeless under all conditions, besides which it must be strongly built, reliable, and easy of access for the repair of the working parts or the renewal of the bars.

These conditions are, of course, difficult of attainment in one stoker. For small grates there are many good and reliable stokers on the market in Britain, but with the larger grates now required the choice is focussed down to two or three. The chain grate has in the past done yeoman work, but it has its weak points, such as the difficulty of burning mixed slack and the difficulty of keeping an even covered grate, the prevention of unburnt coal being dumped, the extra labour in handling riddlings which filter through the grate before coking takes place, and it is unable to comply with many of the requirements set out above. However, when the improvements now being carried out on it are perfected and prove satisfactory in working, no doubt it will come much nearer to the ideal. The underfeed stoker, which has recently been enlarged and strengthened in its mechanical parts, has proved itself, from the author's experience during the last 18 months, most satisfactory, and complies more nearly with the conditions before mentioned. The author therefore considers that the safest arrangement for a large boiler-house is to install a certain proportion of the old reliable chain grate, which has proved satisfactory over a long series of years, and the remaining portion of the newer type, which, while being excellent from results obtained in a comparatively short time, has yet to prove its superiority over a longer period.

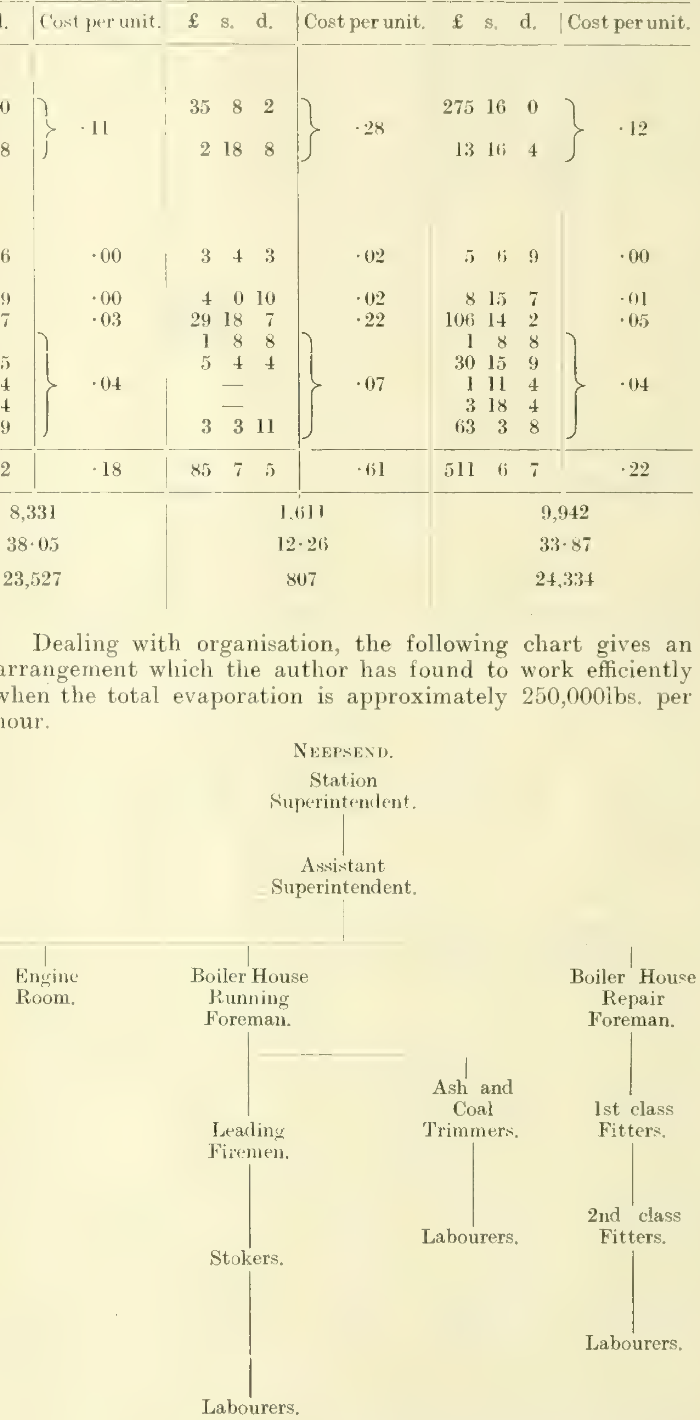
The chief points to consider in the operations of the boiler-house are: (1) Organisation. (2) Coal. (3) Water. (4) Maintenance of plant. (5) Operating costs. (6) Records, tests.

CITY OF SHEFFIELD—ELECTRIC SUPPLY DEPARTMENT.

COMPARATIVE STATEMENT OF WORKS COSTS—Week ending April 30th, 1913.

Particulars.		Neepsend.		Sheaf Street.		Combined Stations.	
Units generated		532,500		33,170		565,670	
	Tons. Cwts. Qrs.	£ s. d.	Cost per unit.	£ s. d.	Cost per unit.	£ s. d.	Cost per unit.
Coal: Neepsend	634 0 0						
Sheaf Street	77 5 3						
	711 5 3	240 7 10	·11 (Coal and Ashes)	35 8 2	·28 (Coal and Ashes)	275 16 0	·12 (Coal and Ashes)
Ashes		10 17 8		2 18 8		13 16 4	
	Gallons.						
Water: Neepsend	78,260						
Sheaf Street	120,700						
	198,960	2 2 6	·00	3 4 3	·02	5 6 9	·00
Oil, Waste, and Stores		4 14 9	·00	4 0 10	·02	8 15 7	·01
Salaries and Wages		76 15 7	·03	29 18 7	·22	106 14 2	·05
Engine-room Equipment		—	·04 (Engine-room Equipment to Lighting and Power)	1 8 8	·07 (Engine-room Equipment to Lighting and Power)	1 8 8	·04 (Engine-room Equipment to Lighting and Power)
Boiler-house Equipment		25 11 5		5 4 4		30 15 9	
Buildings		1 11 4		—		1 11 4	
Sundries		3 18 4		—		3 18 4	
Lighting and Power		59 19 9		3 3 11		63 3 8	
Total Works Cost		425 19 2	·18	85 7 5	·61	511 6 7	·22
Maximum demand ... kw.		8,331		1,611		9,942	
Load Factor Units 100 / Maximum Load 24 7		38·05		12·26		33·87	
Current used on Works		23,527		807		24,334	

Dealing with organisation, the following chart gives an arrangement which the author has found to work efficiently when the total evaporation is approximately 250,000lbs. per hour.



The duties of the superintending staff in the boiler-house are as follows: The boiler-house foreman is responsible for the efficient working of the boilers, and takes daily records of the coal consumption and water evaporation, temperature of flue gases and CO_2, records and makes periodical tests on the boilers. The boiler-house repair foreman works in conjunction with the boiler-house foreman, and is responsible for the quick repairs to the boilers, superheaters, stoker, and econo-

misers, feed pumps, and other auxiliary plant. A chemist is now engaged to carry out all boiler house testing.

All coal delivered to the station is weighed on a weigh bridge and either deposited in the coal shoots, bunkers, or sent to the coal storage ground. At the present time there are 3,000 tons immediately over the boilers and 5,000 tons on the coal storage ground. The method of storing coal depends on the quality. The author has experimented with various qualities and finds that rough slack obtained in the Yorkshire district and stored in large quantities is subject to spontaneous combustion. Consequently nothing but screened nuts are now being laid down and stored in 500-ton lots. The heaps are ventilated and temperatures taken regularly. In this way it is anticipated the coal may be left in the open for a period of years, and that the loss of calorific value will be only 10 to 15 per cent.

With regard to the method of dealing with the coal for storage, considerable capital expenditure is entailed for handling, and is a matter to be considered in the near future by all engineers in order to cope with emergency caused through strikes. The author has considered schemes, and the capital expenditure works out at approximately 15s. per ton of coal stored to about 6ft. high. If, however, a better class of fuel be purchased and the height increased, the cost will be proportionately less. This 15s. per ton of coal stored includes for the provision of a complete scheme for delivering the coal from the wagons on to the storage ground and back again into the coal bunkers over the boiler.

Another system of storing coal where spare ground space is limited is to erect a silo and install the Clayton or some similar system for extinguishing fire. A silo can be built to contain two or three thousand tons of coal, and, after filling it, the entrance manholes must be made air-tight. Through the silo pass two main pipes from which branch pipes can be taken as required. These main pipes connect up to an installation consisting of a generator cooler, blower, and engine. The blower driven by the engine draws air from the silo along one of the main pipes into the generator, where the oxygen of the air combines with sulphur by combustion and forms a mixture of nitrogen and sulphur dioxide. The gas is drawn through the cooler into the blower, which then forces it along a main delivery pipe back into the same compartment from which the air is drawn by suction. The suction and delivery of gas proceed simultaneously, and, as the volume withdrawn is equal to that delivered, there is no leakage beyond what is due to diffusion.

For the extinction of fire in the silo it is not sufficient to merely fill up the silo with inert gas; efficient means must be taken to get rid of the large amount of heat which the coal will hold. By this system, after the fire has been stopped by the introduction of gas, the generator is cut out of circuit and the gas-laden atmosphere circulated by means of the suction and delivery pipes through the cooler, until the temperature of the coal is brought down to normal. Fresh air is then admitted whilst this cooling process is continued, so that the gas is gradually dissipated and re-ignition prevented. Experiments are also now being carried out to see the effect of turning a portion of the flue gases into enclosed bunkers in which coal fires occur. The coal is purchased to a rigid specification, and if the calorific value on delivery is below the specified amount a corresponding reduction is made in the price.

The water is measured by a recorder and this instrument is placed between the overhead hot well and the pumps, so that the records are obtained of the total water evaporated. Similarly the water used by the turbines is recorded, and the difference in the two readings gives the loss, after making allowance for water returned from steam traps and the exhaust from the feed pumps. Frequent tests are taken to ascertain the hardness of the water, and the degree of concentration in the boilers. No softening plant is required as the supply for make-up contains only 3° of hardness, and this figure is generally less in the winter season.

Complete records are kept on a card system as to the cost of maintenance of each boiler complete with stoker, superheater, and economiser.

Operating Costs.—A copy of the weekly costs sheet used in Sheffield is given on page 580, the figures being the actual figures obtained for the week named.

With regard to the suggestion made from time to time lately, that large electric power stations should be equipped with by-product plant, it will, of course, be necessary to bear in mind, that if such plant were installed for distilling the coal and making gas either for burning under the boilers or for driving a gas engine, the capital expenditure per kilowatt of plant installed would have to be considerably higher than it is at present, in an ordinary coal fired steam turbine station. In view of this larger capital expenditure, it will be necessary to carefully arrive at the percentage of the total plant which could be economically operated by means of the fuel obtained by this by-product plant.

In looking through his present load curves, the author arrives at a figure of 2,000 kw. of plant installed out of a total of 25,000 kw. It would appear, therefore, other things being found satisfactory, that it might be economical to provide by-product plant for about 8 per cent. of the total plant of a power-house, and this plant should be run at practically 80 per cent. load factor to make it a paying proposition. Of course, if such a thing as by-product plant be attached to a power-station, a much larger area would be required, and this in many places would be difficult to find with the requisite facilities as regards water, coal, &c.

The problem of high superheat is looming in the not very distant future, and engineers and manufacturers will have to face a new set of conditions, when a dull red gas is being passed through the steam pipes and valves.

Finally, the author wishes to impress on all the great importance of a present-day boiler-house and plant; it is, in fact, of paramount importance, where more money can be saved than anywhere else in a power station, by employing and paying highly-trained and capable men who can bring scientific knowledge to bear on the many important problems that present themselves for investigation.

INSTITUTE OF MARINE ENGINEERS.

VISIT TO THE WORKS OF MESSRS. J. & E. HALL, LTD.

ON Saturday, June 6th, a visit was paid by members of the Institute of Marine Engineers to the works of Messrs. J. & E. Hall, Ltd., Dartford. Founded in 1785, the manufacture for which the firm originally gained a reputation included paper making machinery, gunpowder plant, marine and beam engines, elephant boilers, and all classes of mill work. The first trunk engines ever made were designed and constructed at the Dartford Ironworks, and as long ago as 1836 a pair of 60in. beam engines, fitted with surface condensers, were designed and made there for the s.s. "Wilberforce." The carbonic anhydride (CO_2) refrigerating machines for marine and land work were introduced by them in 1888. In 1910 the manufacture of ammonia compression machines was added. The facilities for the construction of these machines, and of the "Hallford" heavy motor-vehicles, a recent and equally successful branch of the company's activities, are of the most modern description.

In the pattern shop, plans and photographs of some of the larger orders in hand were examined. The marine type most in use in the larger vessels is the duplex machine, fitted with compound steam cylinders, the high-pressure cylinder being on one side and the low-pressure cylinder on the other, with a steam surface condenser in the front part of the machine. The two machines are so arranged that either both sides can be worked jointly, or, if desired, one side (viz., one compressor with its condenser and evaporator) can be disconnected and the other side worked by itself, the full advantage and economy of the compound engine being retained. This type of machine is designed to suit the limited height of the 'tween decks, the largest size being less than 7ft. in height.

The power plant consists of three Lancashire boilers, two being 8ft. by 28ft., and one 9ft. by 28ft. 6in. The two smaller boilers are used as a standby for heating purposes in winter; the larger boiler provides all the steam for driving the works. It was made by Davy Bros., of Sheffield, and is fitted with their system of balanced draught, with an air economiser, superheater, and water economiser. It easily evaporates 10,000lbs. of water per hour from 180° Fah. to 180lbs. pressure superheated to 550° Fah. The feed water is measured by a Lea recorder. There are three generating sets, two of Willans & Robinson's central valve type of 220 kw. capacity each, which act as a standby. The main set is by Belliss & Morcom, triple expansion, with a capacity of 400 kw. In addition, there are two motor generators for working off

the town supply, and two rotary transformers for electric welding. For testing purposes there are four air compressors, two of the 3-stage type compressing to 95 atmospheres, and two low-pressure type compressing to 100lbs. per square inch.

In the machine and erecting shops, which naturally cover the larger part of the workshop area, the various stages of construction of compressors, condensers, &c., were seen. In these shops are some of the best types of modern machines, including a large hexagon turret lathe and semi-automatic lathes, automatic stud-making and other machines. The boring machines are necessarily of good construction, the compressors for the large refrigerators all being bored out of the solid steel forgings. High-speed steel is used for the cutting tools. A detail of interest is the disc safety valve, which is an important feature in the Hall machines. It consists of an ordinary spring safety valve, at the base of which is a thin copper disc, which ruptures when the pressures come below that to which the machine as a whole is tested. In the coppersmith's shop the method of brazing the pipes in the construction of the grids was demonstrated, also the various tests to which the copper is subjected. End-joining of the pipes by electric welding was also shown, this method having been found to give the best results without danger of swelling or constriction of the metal. An ingenious pipe-bending machine, designed and made in the works, was also inspected.

After visiting the foundry, which is at present undergoing considerable extensions, the party was conducted through the new works for the construction of motor-vehicles. The machine and erecting shops are under one roof, the stores being placed centrally between them. In addition to overhead cranes in each bay, the whole of the works is intersected by a system of light tramways. The machine tools are of the most modern pattern, highly specialised for the work, systematically grouped and driven by electrically-operated line shafting, each group of tools having its own drive. Capstan and other lathes, multiple-spindle and capstan head drills, milling and gear-cutting machines are well represented. Ample provision is made also for the case-hardening and heat treatment of the various parts.

An interesting demonstration was given of the method by which the efficiency of the refrigerators is accurately tested. The party was afterwards entertained to tea, and votes of thanks to the firm and to the gentlemen under whose guidance the visit was made were proposed and seconded by Mr. Jas. Shanks and Mr. E. Seabury respectively. Mr. Willcox and Mr. Buchanan responded on behalf of the firm.

Royal Institution.—A general meeting of the members of the Royal Institution was held on the 8th inst., the Duke of Northumberland, president, in the chair. Mr. H. B. Hans Hamilton, Sir William H. Lever, Bart., Mr. Percy St. C. Matthey, J.P., Mr. H. W. P. Matthey, Miss Matthey, Mr. J. F. C. Snell, and Mr. T. J. Taylor were elected members. The secretary announced that the President had nominated the following gentlemen as vice-presidents for the ensuing year: Lord Blyth, Mr. J. H. Balfour-Browne, Mr. Charles Hawksley, Dr. Donald Hood, Lord Moulton, Mr. E. Pollock, Sir James Crichton-Browne (treasurer), and Mr. Alexander Siemens (secretary).

A Null Method of Testing Vibration Galvanometers.—In a paper on this subject read by Mr. S. Butterworth, M.Sc., at a recent meeting of the Physical Society of London, the author pointed out that the methods usually employed in the determination of the constants of a vibration galvanometer involved the measurement of a deflection under three different conditions. Two of these deflections could only be obtained very approximately. By extending the theory of the vibration galvanometer the author showed how the constants could be determined by methods which involved only the measurement of one deflection. The remaining measurements were carried out on an alternating-current bridge, and the results obtained were practically independent of the wave-form of the source. The principle of the method depended on the fact that a vibration galvanometer behaved as a parallel combination of a conductance, a capacity and an inductance, in series with a resistance. He showed how to balance such a combination, and illustrated the method experimentally. The constants of various galvanometers were quoted in order to show the applicability of the method.

THE CARE AND PROTECTION OF WIRE ROPES.

BY L. BALLIET.

WIRE rope for mine hoisting needs proper care and attention. When purchasing the quality of the rope should be considered rather than the price. We can readily appreciate that the winding of the cable around the drum, the bending of the cable over the sheave, and every swing, jar, vibration or "stretch" of the rope, means friction of every strand over every other strand, and of every wire over every other wire throughout the length of the cable. The safety and utility of the ropes depend upon the manner in which they are cared for. The sheave wheel should never be less than 30 times the diameter of the rope, and it is better if the sheave wheel is 40 to 60 times the diameter of the rope. In fact, the larger the sheave wheel, the better it is for the rope. One can easily understand that by bending a 1in. cable around a 30in. sheave, the friction of the wires over each other will be far greater than by bending the same rope around a 60in. sheave. Furthermore, it takes more power to bend a cable around a 30in. sheave than around a larger one.

From the foregoing it is clearly evident that wire ropes should be lubricated, and lubricated with oils and greases that will penetrate between the wires of the strands. This not only makes friction lighter, with less wear upon the wires composing the rope, but it prevents rusting and pitting of the interior wires. Rope should never be coated or "doped" with anything that will harden on the outside, for this coating will crack by bending over the sheave and around the drum, and when it is lowered into a damp shaft, or when the humidity of the air is high, moisture will penetrate the cracks of the coating and work its way into the very centre of the cable. This will in time cause the hemp core to become water-soaked, and it will act like a wet sponge in holding the moisture. In this way the wires on the inside of the rope will rust and pit, even though the coating may appear to be perfect upon the outside of the cable. Many a cable is in operation where the interior wires have been completely eaten away, and the entire load is being carried by the outside wires. This is extremely dangerous, because in the twist of the rope any of the wires may come to the outside at some place, and the only thing that holds them together is the friction exerted by the pull that is upon them. When the wires of a cable are worn half in two by abrasion on the outside, and rusted and pitted half in two by moisture on the inside, there is not much strength left in the rope. Ropes that run in dry shafts should be lubricated for the reduction of friction; ropes that run in damp mines should be lubricated to prevent rusting and pitting. Again, I repeat that ropes should never be coated.

Good ropes should be elastic; they should have a "stretch" in them that is noticeable. If you run a loaded car upon a cage without setting the chairs, you will notice several inches of spring due to the elasticity of the cable. When a rope loses its elasticity, its usefulness and safety are gone. It should be immediately discarded and a new one provided to replace it.

Ropes should be reversed upon the drum occasionally. The free end that descends into the mine should be brought up and wound upon the drum, while the other end is allowed to descend into the mine. It is not a hard job to reverse a cable, nor does it take much time. Two or three men can do it in a few hours. The writer has frequently reversed cables by disconnecting the cage at the bottom, or taking it out of the shaft entirely at the top until the cable is reversed. The writer's method is to pull out enough of the cable to have plenty of it free to start the winding on the drum, and clamp it to the gallows frame, after putting a 30in. sheave in the loop thus formed. This sheave is mounted like the fall-block used on any derrick, and to the hook is fastened a weight. Generally the weight consists of a bucket of rock. The engineer then allows the bucket to sink into the mine, which doubles the rope down the shaft. When the rope is nearly unwound from the drum, it is likewise clamped to the gallows frame and removed from over the sheave. The free end is then run up over the sheave and fastened on the drum.

The clamp from this end of the rope is then removed, and the engineer winds it upon the drum until the bucket of rock is brought to the surface again. The weight and fall block are then removed from the cable, and the remaining clamps removed. The cage is attached to the cable which is thus reversed.

Another thing is that 15ft. or 20ft. of cable should be cut off and examined every few weeks or months. There are two reasons for this: The first is for the inspection of the inside wires of the cable, and the first 15ft. above the cage is the part that is subjected to the severest wear, and furnishes a good place for examination. The next place of severe wear is where the rope is bent over the sheave when the cage is standing. By cutting off 15ft. or 20ft. it is necessary to unwind that amount of rope from the drum in order to reach the bottom. Hence, a new spot is furnished to take the strain where it stands over the sheave. It is an easy matter for the sheave wheel to get out of alignment. Head frames are very frequently built upon filled ground around the collar of the shaft, and if one leg of the frame settles more than another, the sheave wheel will be out of line, and the wear upon the cable will be increased, both in the sheave wheel and upon the drums.

There is still another important matter in the handling of wire ropes, and that is the matter in which thimble-eyes are put on the cables when it is necessary to loop the cable and bend it back upon itself. Care must be taken to preserve the twist of the cable around the thimble-eye in order to make all the strands have their proportion of the outside circumference of the loop. It is evident that the outside circumference would be longer than the inside of the loop around the thimble-eye, and if the twist of the cable is not carefully preserved, some of the strands will have to pass a longer distance than the others. This will increase the tension on the strands that follow the outside of the circle, and will make them carry the entire load. Not only is this true around the thimble-eye, but it carries the load through the entire length of the cable, while the strands that have the shorter circumference on the inside of the loop will be slack.

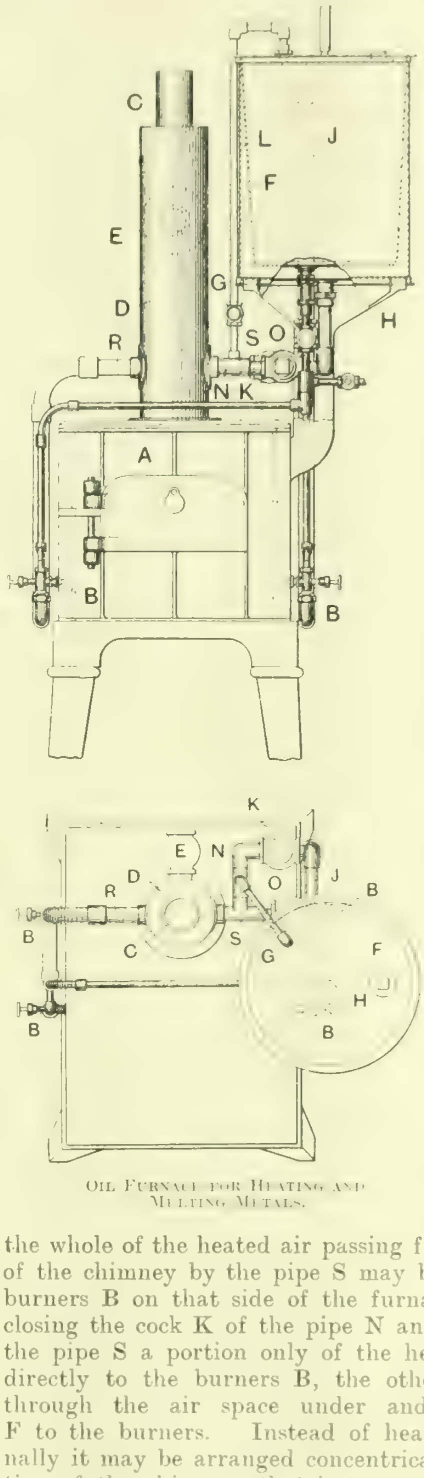
Still another point in the use of wire rope may be mentioned at this time, and that is the question of rapid hoisting, which should be carefully avoided. It is much better to double the load than it is to double the speed. In doubling the load we have a friction of but once over the sheave, once around the drum, and but one period of vibration and swing of the cable to overcome; while if the speed is doubled we have the same friction to be overcome twice to accomplish the same tonnage. In slow hoisting the molecular vibrations are slower and less fatiguing on the metal of the wires. The slower speed is also less liable to accidents. Leaving out of consideration the weight of the hoisting rope, the friction of the cage upon the guides, friction of the rope, and the mechanical friction and motor losses, we obtained some very interesting figures on cable strains by using a dynamometer between the cage and the cable. The following tests were made at the Buckeye mine:—

	Pound pull Required.
Weight of the empty skip is 1,600lbs.	
When started very gently and lifted empty...	1,600
When started with 2½in. of slack out	2,240
When started with 6in. of slack out	3,580
When started with 12in. of slack out	4,920
Weight of skip with 3,000lbs. ore or rock loaded is 4,600lbs.	
When started gently without jerk	4,600
When started with 3in. of slack out	8,230
When lifted with 6in. of slack out	10,810
When started with 9in. of slack out	12,880

All of the above figures are made testing cable unbalanced. To find the motor torque add 43 per cent. as a good average, including friction and cable weight to the bottom of the shaft. The use of cage chairs in the shaft has been abolished at the Buckeye mine, because they are the most dangerous obstruction that has ever been tolerated by the engineering profession.—"Mining and Engineering World."

OIL FURNACE FOR HEATING AND MELTING METALS.

WE illustrate herewith a design of oil furnace for heating and melting metals, the invention of Mr. P. W. Alley, of the Great Western Works, Pneumatic Engineering Company, Ltd., Sydenham Road, Birmingham, embodying several improvements more particularly relating to the method of heating the oil and the air. Referring to the illustrations, A is the furnace which is provided with two oil fuel burners B at each side. C is the waste gas flue or chimney of the furnace by which the products of combustion and waste gases escape, and D is the annular chamber on the chimney through which the air supplied to the burners B is passed so as to effect the heating of the air before it reaches the burners. The air enters the annular chamber at E and passes out by the pipes R S respectively at opposite sides of the lower end of the chamber D. Adjacent to the chimney C and surrounding air-heating chamber D is arranged the oil tank F, this tank having a double side and double bottom. The hot air escaping from the chamber D by the pipe S passes partly to the top surface of the oil in the tank F by the pipe G for the purpose of putting pressure on the oil and partly to the air space between the tank F and the outer casing L by the pipe H, so as thereby to effect the heating of the oil in the tank. The air passes from the jacketed space around the tank F by the pipe J to the two burners B at one side of the furnace. The burners B at the opposite sides of the furnace are supplied with hot air directly from the chamber D by the pipe R.



OIL FURNACE FOR HEATING AND MELTING METALS.

The regulation of the temperature of the air space under and around the oil tank is provided by employing a branch pipe N and control cock K, by which the whole of the heated air passing from the jacketed portion of the chimney by the pipe S may be passed directly to the burners B on that side of the furnace and by more or less closing the cock K of the pipe N and opening the cock O of the pipe S a portion only of the heated air may be passed directly to the burners B, the other portion being passed through the air space under and around the oil tank F to the burners. Instead of heating the oil tank externally it may be arranged concentrically on the jacketed portion of the chimney, that is to say, two concentric annular chambers may be arranged on the chimney, the inner one having for its object the heating of the air to be delivered to the burners and the outer chamber constituting the oil reservoir, the oil in which is heated by the wall of the heated air chamber.

THE SCHLOTTER BLOWER.

In an article in "Zeits. fur Dampfkessel und Maschinenbetrieb," translated in the "Proceedings of the American Society of Mechanical Engineers," Max Berlowitz states that for liquids and gases centrifugal pumps have been used nearly exclusively, while with helical wheels neither large pressures nor economic efficiency has so far been obtained. This is all the more regrettable because spiral pumps can be very conveniently installed and require much less space than centrifugal pumps, and also possess important advantages in that they are reversible and may be run at high speed. It now appears that a German engineer, G. A. Schlotter, has succeeded in building a spiral pump which can be used as a blower (Siemens-Schuchert Co.) It consists of a rotor, distributor, and a cast-iron casing containing the rotor and provided with supports. The rotor has five vanes, the

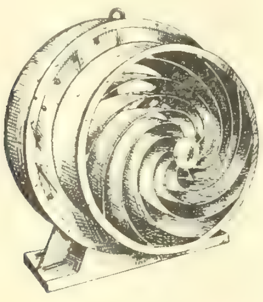


FIG. 1.

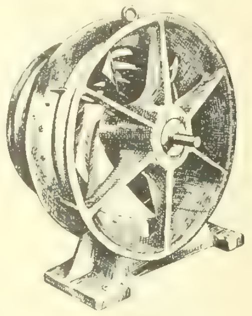


FIG. 2.

pressure surfaces of which are pure helical surfaces. In accordance with the use to which the apparatus is to be applied, they may be made either of some light metal or of bronze, and, when run at high speeds, may be reinforced with supporting rings. The distributor has from eight to ten blades, with a curvature opposite to that of the vanes of the rotor, and, in the case of small units, is made of wrought iron; in larger units, of cast iron. When gases containing acids are to be handled, the rotor and distributor are galvanised, while for hot gases they are covered with a fireproof dressing. Ball bearings are used exclusively, and only need to be taken out to be cleaned and refilled with grease once or twice a year. When hot gases are being handled, the bearings are water cooled. Since a bearing has to be provided in any case to take up the axle thrust, each blower can be used either vertically or horizontally, and, if desired, can be installed at any angle of inclination. The vanes and distributors are shown respectively in Figs. 1 and 2.

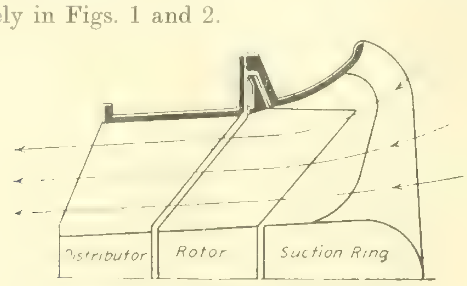
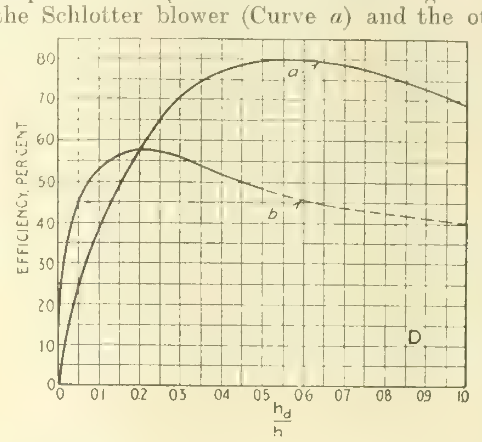


FIG. 3.

The action of the blower is as follows: It gets air by suction from a semi-spherical zone, as shown in Fig. 3, and presses it into a close bundle of vanes, easily rotating and converging toward the axis. The approximate path of stream lines is indicated by arrows, and it will be observed that the air particles in their flow do not remain in the same section of the axis, but perform a rotary motion all around the axis. Hence in the passage of air, shocks and eddies are avoided as much as possible, and practically all the energy applied at the driving end, with the exception of unavoidable losses due to friction in the bearings, and air friction is utilised in the normal operation of the engine. This blower therefore shows, under favourable conditions, a maximum efficiency of 80 per cent. or more. The author considers it a happy idea that a pressure piping or very flat diffusor is added under the blower, since the kinetic energy of the air can be transformed into pressure when leaving the diffusors. When a short exhaust angle is added, the exchange efficiency of the apparatus falls. Still more important, however, than the maximum efficiency of the apparatus is the fact that the efficiency curve of the blower is very flat, so that its construction produces an unusually high efficiency through wide ranges of loads from the highest back pressure up to free outflow.

For purposes of comparison two curves are given in Fig. 4, one for the Schlotter blower (Curve a) and the other for a



Where $h_d = \frac{\gamma v^2}{2g}$ = the dynamo pressure head in the cross-section of outflow, and h is the total pressure produced by the blower.

FIG. 4.

well-known centrifugal blower (Curve b), for the ratio $\frac{h_d}{h}$, where $h_d = \frac{\gamma v^2}{2g}$ is the dynamic pressure head in the section of outflow and h is the total pressure produced by the blower. The construction of the blower permits it to be used for handling air and gases of any temperature, as well as for handling gases containing dust and shavings. It is to be recommended particularly for places where saving in space and power is important and lower weight and easy installation considered to be of value.

ESTIMATION OF SULPHUR IN PIG IRON AND STEELS.*

BY G. MISSON (SERAING).

COLORIMETRIC processes for the estimation of sulphur have hitherto been prone to errors arising (1) from the sample taken being too small, and (2) from the fact that the acid employed for solution has been too diluted, and does not drive off the whole of the sulphur as sulphuretted hydrogen.

Further, these methods have been inapplicable to the analysis of pig irons. The process which since October, 1910, has been employed at the laboratory of the Cockerill Company is equally serviceable for the analysis of basic and acid pig irons, and for that of steels. The amount taken for assay is 1 gr. of the sample, and solution is effected in the cold by hydrochloric acid of 1·14 specific gravity, made by mixing 7 litres of concentrated hydrochloric acid with 3 litres of water.

Reagents and Apparatus required for the Estimations.—(1) A piece of white felt 10 cm. square and 5 mm. in thickness. (2) Slightly conical glass vessels with thick rims, 80 mm. diam. and 95 to 100 mm. in height (ordinary No. 4 ice-glasses are used). (3) Paper, impregnated with a solution obtained as follows: Take 10 grs. of pure powdered arsenious anhydride and 30 cub. cm. of concentrated hydrochloric acid; shake; add about 500 cub. cm. of boiling water, heat until dissolved, and make up to 1 litre. In this solution leaves of filter paper are soaked (Schleicher No. 598 in reams). They are allowed to drain over glass rods. The paper while still moist is cut up into pieces 10 cub. cm. square and preserved, damp. (4) Pieces of ebonite, 10 cm. square and 1 or 2 mm. in thickness. (5) Discs of lead weighing about 500 grammes. (6) Benzine (specific gravity 0·710). (7) Steels, basic pig irons, and Bessemer pig irons standardised as to their sulphur contents.

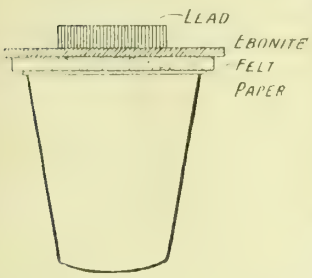
Details of the Operation.—The sample, weighing 1 gr., is introduced into the conical vessel illustrated; 10 cub. cm. of benzine and 50 cub. cm. of hydrochloric acid are added, and the vessel covered over by means of a piece of the arsenious paper, over which is placed a piece of felt, and then the square

* Paper read before the Iron and Steel Institute, May, 1914.

of ebonite, held down by the lead disc. The sulphuretted hydrogen and hydrogen evolved escape uniformly through the entire surface of the paper. The sulphuretted hydrogen is decomposed, and leaves a yellow stain. The yellow colouration is distributed very evenly over the whole surface, owing to the presence of the piece of felt. The standards are tested simultaneously with the samples, and the tints are compared by transmitted light. The following standards are employed:—

For steels .... 0·035 and 0·065 per cent.
For basic pig irons ... 0·05, 0·12, and 0·17 per cent.
For Bessemer pig irons 0·05, 0·12, and 0·17 per cent.

The duration of a test depends, in the case of steels, on the size of the drillings subjected to analysis. With convenient-sized drillings, and with powdered pig irons, the time required may in certain cases not exceed an hour, and a single operator can carry out a large number of operations, as these require, so to speak, no manipulation whatever apart from the weighing out. This process is particularly to be recommended when there are a great number of estimations to be made. In the laboratory in question a hundred per day is an average number. Once started, the tests should not be touched. Any agitation, by breaking up the film of benzine floating on the acid, will produce stains on the surface of the paper.



Below are given a number of the results obtained by this new process compared with those obtained by the gravimetric and volumetric processes ordinarily employed.

Steels.

No. of steel.	New method.	Evolution method and titration of the Cadmium Sulphide by Iodine and Hyposulphite.	Old method of Weighing Barium Sulphate.
	Per cent.	Per cent.	Per cent.
9057	0·07	0·07	0·065
9072	0·032	0·03	0·028
9256	0·048	0·046	0·045
9295	0·035	0·036	0·037
396	0·048	0·05	0·043
72	0·027	0·028	0·023
565	0·038	0·04	0·038
374	0·04	0·04	0·038
613	0·025	0·03	0·026
650	0·047	0·044	0·049
665	0·04	0·038	0·037
741	0·048	0·046	0·05
34	0·028	0·026	0·026
821	0·033	0·036	0·036

Pig Irons.

	New Method.	Evolution Method and Titration of the Cadmium Sulphide by Iodine and Hyposulphite.	Old Method of Weighing Barium Sulphate.
Basic Pig Irons.			
	Per cent.	Per cent.	Per cent.
Cupola—Oct. 22nd.	0·15	0·146	0·162
No. 3 Blast-furnace—Dec. 22..	0·06	0·06	0·065
No. 6 Blast-furnace—Dec. 22..	0·108	0·098	0·107
Mixer—Dec. 23–24.	0·086	0·08	0·082
No. 4 Blast-furnace—Dec. 24..	0·074	0·07	0·08
No. 2 Blast-furnace—Dec. 28..	0·09	0·095	0·086
No. 3 Blast furnace—Dec. 28..	0·09	0·082	0·082
Mixer—Dec. 27	0·078	0·07	0·07
Bessemer Pig Irons.			
No. 7 Cast	0·02	0·018	0·026
,, ,, ...	0·034	0·034	0·037
,, ,, ...	0·038	0·04	0·041
,, ,, ...	0·03	0·03	0·031

THE FLYING-MACHINE FROM AN ENGINEERING STANDPOINT.*

BY FREDERICK WILLIAM LANCHESTER, M.INST.C.E.

(Concluded from page 566.)

(12) *Landing Gear.* 8. The question of alighting mechanism in detail next claims our attention; this is necessarily of two distinct types depending upon whether the machine is designed for land or for marine usage. Taking first the land or military type of machine, the essential features comprise ordinarily a pair of pneumatic-shod wheels (in some cases two pairs) arranged on a common axis somewhat forward of the centre of gravity of the machine and supplied with a rudimentary elastic suspension of some form, in addition to runners or skids to take the "bump" in emergency, and the provision of some kind of temporary tail support, consisting either of a castor-pivoted wheel, or (as more generally the case) of a simple spring-controlled skid. It was at one time believed to be essential that the alighting wheels should be all castor-pivoted or *orientable*, the intention being to take care of the relative motion of the ground when alighting across the wind;† experience appears to show that with

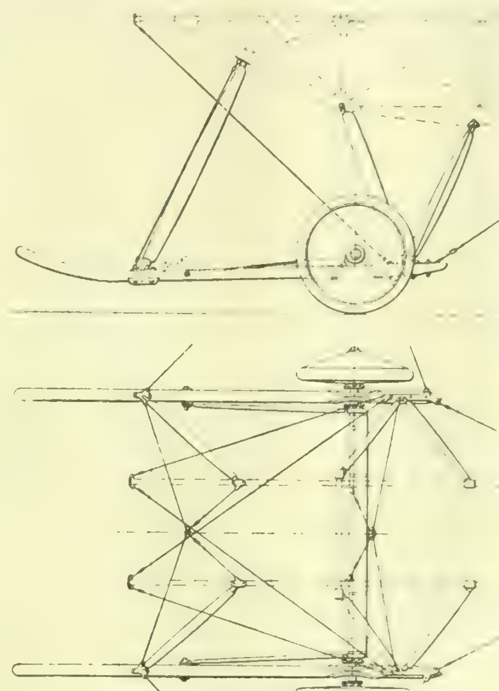


FIG. 31.

reasonably careful handling this provision is unnecessary. Two types of suspension are illustrated in Figs. 31 (R.A.F.) and 32 (Blériot); it will be noted that in both cases the medium employed to absorb the shock is rubber; this is preferable to steel (as universally employed on road vehicles) for two reasons; firstly, the energy good vulcanised rubber will absorb is far greater than is the case for steel; it runs to some 500 to 1,000lbs. per pound (some 10 or 20 foot-lbs. is all that may be allowed for steel); and secondly, the signs of fatigue in rubber are evident to the most casual observer and the rubbers are cheap and easy of replacement. The alighting wheels with their associated parts are mounted on a structure commonly known as the landing chassis whose function is to raise the machine proper a sufficient height above the ground to provide clearance for the propeller, aerofoil, &c.; unless careful design and workmanship is put into the landing chassis its "spidery" proportions necessary to give clearance may, on the one hand, constitute a source of weakness, or, on the other, give rise to excessive resistance. Owing to the liability of the landing chassis to injury it is clearly desirable

* The "James Forrest" Lecture, 1914, delivered before the Institution of Civil Engineers, May 5th, 1914.

† Messrs. Voison Brothers, in the days of their pioneer work, attached great importance to this point. They attributed the early success of Farman on his Voisin machine largely to the fact that this feature was embodied in his machine.

that its structure should be complete within itself, yet this is very difficult of achievement in actual design: more often than not there are members in common to the landing chassis and the aerofoil structure or the fusillage. This must be considered a weak point in any design, since it involves the risk that some essential flight organ may on landing be strained or otherwise injured or at least stressed beyond the limit for which it has been designed.

In spite of all that has been done up to the present the landing chassis is only able to take a very moderate "bump" with safety, a 1ft. free fall on to a hard surface is as much as can be deemed safe in the best of existing machines, a free fall of 4ft. or 5ft. would lead to almost certain failure. This requires that, in landing, a machine should never under any circumstances be allowed to take the ground with a greater vertical velocity component than 8ft. per second. Assuming a gliding angle of $\frac{1}{7}$, this means that a machine flying at 38 miles per hour (56ft. per second or ft./sec.) could be allowed to take the ground (presuming the latter horizontal), without intervention of the pilot, but for any higher velocity of flight its course must be eased or flattened; in actual practice it is, of course, part of the art of flying to avoid all shock when alighting, no pilot would think of taking the ground without at least making his best effort to flatten his angle of descent. There is probably a future for some form of

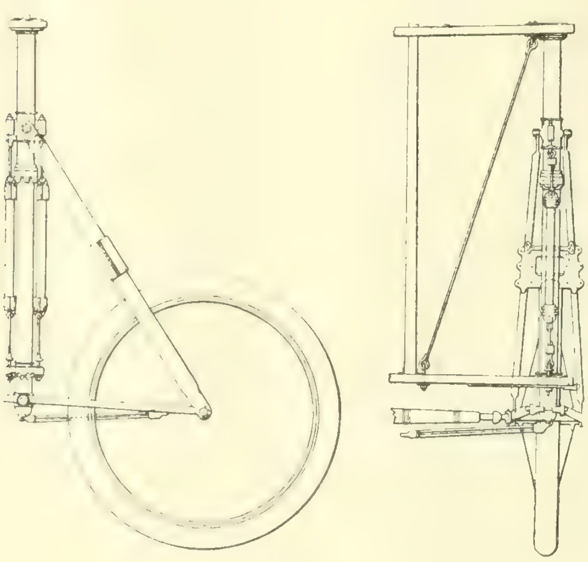


FIG. 32.

hydraulic-pneumatic device; already several attempts have been made in that direction.

Passing now to the marine type, we find in the earlier examples a landing chassis of the ordinary pattern fitted with a pair of floats in place of wheels and skid, and a temporary tail support in the form of a third float arranged aft under the tail member. In the earlier machines these floats were little more than boxes of rectangular section, Fig. 33; more recently there has been a tendency to give to the floats a more boat-like form,* surfaces of single or double curvature being adopted in place of flat, and so the liability to being stove in has been reduced to a minimum. The double-float support has proved itself suited to comparatively smooth water, but a strong feeling exists at the present time that for machines intended to serve on the high seas that construction will be abandoned in favour of the single central boat, as already to be seen in the Curtis and Sopwith machines (Fig. 34); here auxiliary floats or bob-floats are fitted to the extremities of the aerofoil to give stability to the machine when resting on the water, and to avoid damage to the aerofoil when getting under way or when alighting

The main floats, whether single or double, require to be constructed to rise in the water on the same principle as the so-called hydroplanes or skimmer craft, being designed with the usual stepped bottom; a single step is found to give the best results. The design of floats or hull for a marine machine must be regarded as still in an early stage of development, and much will depend in the future on the general evolution of the machine as to what form of float gear will ultimately be found most appropriate. The author is of opinion that as a development of the single boat type at present existing it would appear to be desirable to bring the motor or motors, and other heavy parts as far as possible, down into the hull,

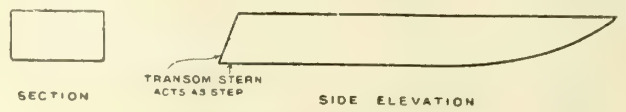


FIG. 33.—EARLY TYPE (SMOOTH WATER) FLOAT.

and design the boat as a thoroughly sea-worthy craft with proper metacentric height and fitted with its own (marine) screw propeller so that it is capable of being navigated independently of its flight organs (Fig. 35). In such a design it would evidently be necessary to drive the propellers through a belt, chain, or gear of some kind, and mechanism would be provided by which the pilot could jettison the superstructure in emergency. Such a machine would be essentially one of considerable size, and would probably be fitted with two, three, or even more engines, with a total of over 500 h.p. The weight of such a machine would require to be some 3 or 4 tons, and would be capable of making port under its own power in the event of the flight organs being abandoned.

(13) *Acentric Types of Machine.*—The type of machine here suggested would be liable to certain objections on the ground that the line of the propeller thrust is acentric, being situated considerably above the centre of gravity and probably also above the centre of resistance of the machine, conversely the centre of gravity would be considerably below the centre of resistance; these are objections which have been raised with regard to some existing machines. It is undoubtedly desirable, where other considerations permit, to bring the centre of propulsion, centre of resistance, and centre of gravity to approximately the same level. There is no fundamental difficulty in flying a machine in which this condition is not complied with since any pitching moment that results from the want of concentricity can be corrected by suitably arranging the centre of gravity. Serious difficulty, however, is liable to arise in the event of a sudden change in the mode of flight such as is brought about when the engine is cut out. Under these conditions the machine being propelled in gliding flight by a component of gravity instead of by the propeller thrust, a change of pitching moment takes place equivalent to the total resistance of the machine multiplied by the vertical distance between the line of propulsion and the centre of gravity. In a machine of the type above suggested such a change of moment would be the equivalent of a movement of the centre of gravity through a distance of nearly 2ft., a change which we must regard as of dangerous magnitude.

The position is that shown diagrammatically in Fig. 36, in which it will be seen that the resultant of gravity and the propeller thrust passes some considerable distance in front of the centre of gravity, whereas in gliding flight the resultant

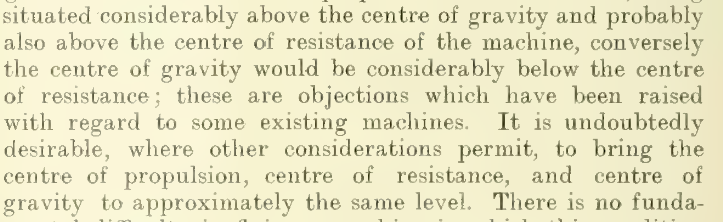


FIG. 34.—CURTIS FLYING BOAT, 100 H.P.

of the lifting and propelling forces *is* the force of gravity, and so passes through the centre of gravity.

It has been suggested that by arranging the tail plane (and elevator) in the wake, in the propeller slip stream, in fact, and giving it an upward rake, in other words, by employing a negatively loaded tail, the tail may be made to supply a counter-vailing pitching moment when the propeller is at work; thus whilst the direct effect of the propeller is to tend to lift the tail and depress the nose of the machine, the

* An instructive series of trials have been made in the Yarrow Tank at the National Physical Laboratory. Report Advisory Committee, 1912-1913, Memorandum No. 70 (Baker and Miller).

indirect effect brought about by the action of the slip stream on the upturned tail will be the inverse. It might be possible in this way to correct a small want of concentricity of the propeller axis, but such a method would scarcely be applicable to the case in point. In order that the method in question should be effective, the slip stream must be discharged radially from the centre of gravity of the machine, that is to say, the general body of air discharged in the slip stream must be so deflected that its

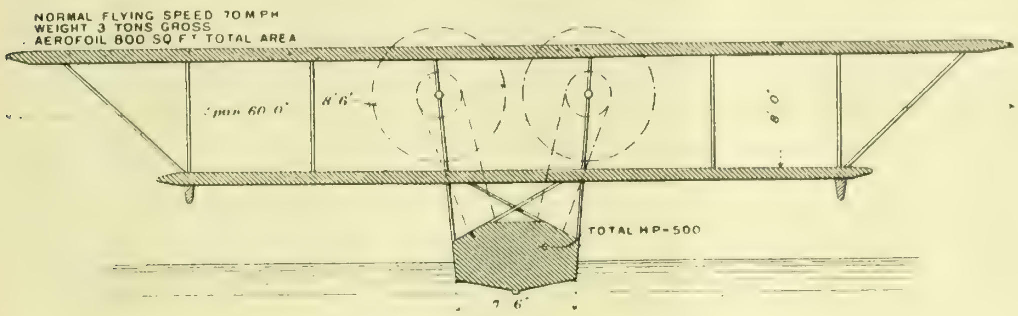


FIG. 35.

moment of momentum about the centre of gravity is zero. Roughly speaking, this means that the tail, as shown dotted in Fig. 36, must be set at such an angle as, if produced, would pass through the centre of gravity of the machine; the double-headed arrows show the slip stream diverted as theory requires. The method is evidently impracticable; not only is the tail angle as necessitated altogether excessive, but also the whole story has not been told—the tail would require to be "feathered" immediately the propeller ceases its function, otherwise it would continue to supply a moment of some magnitude when no longer required.

It is of interest to examine in greater detail the behaviour of a machine such as we are considering under flight conditions. It is clear that if at any instant the engine is switched off two things happen, firstly, as in a machine of the concentric type, the supply of energy being withdrawn the datum of the phugoid chart takes a downward trend, its down slope is that of the gliding angle, Fig. 37, datum 2. Secondly, since the withdrawal of the thrust, reaction is in effect equivalent to a movement backward of the centre of gravity, the angle of attack of the aerofoil is increased and the natural velocity of the machine is reduced, and H_n is diminished to a corresponding degree. The conditions are thus represented by the upper diagram in Fig. 37; the reduction of H_n being calculated, we consult the phugoid chart and select the curve to correspond; as shown this has been taken as curve G from Fig. 2. In the lower diagram (Fig. 37) a similar construction has been shown for a machine nearly concentric as to its thrust; the resulting phugoid here corresponds to that labelled C in Fig. 2. The case of least disturbance is that in which the original flight path picks up the new flight path at its point of inflection; this is the case if the propeller axis

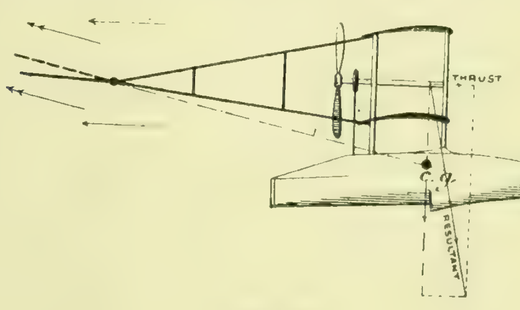


FIG. 36.

is slightly below the centre of gravity, since then on cutting out the engine the value of H_n is slightly increased; this is as actually represented on the lower diagram.

At present there are difficulties, of the character and extent outlined, standing in the way of development in the direction indicated; they are difficulties that will without doubt be eventually overcome.

(14) *Stability and Control.* In the present lecture all questions of stability in the ordinary sense have been taken for granted. The problems of longitudinal stability, lateral and directional stability, and spiral or rotative stability, though of vital import to the aeronautical engineer, are primarily matters for the physicist and mathematician, the engineer can well afford to leave questions of this character in the hands of the specialist.

There is perhaps less excuse for the absence of all mention of controlling mechanism. A great deal might be added on that subject without going beyond the scope of the title; however, since the question of control is closely wrapped up with considerations relating to stability, and since it is necessary to draw a line at some point, the omission is one of expediency rather than logic.

The question of stability is not, as is frequently supposed, one that is in any sense obscure; in fact, from the scientific point of view, the present position is at least satisfactory; it can be said without exaggeration that we have a great deal more knowledge on the subject than we are at present able to utilise.

There is very little of importance, specifically relating to the stability of the flying-machine, that has been written, either before or since, that will not be found either in the work of Dr. Bryan* or in "Aerial Flight."† A few notes have appeared in the various reports of the Advisory Committee for Aeronautics, but not very much; two short notes of a somewhat trivial character appear in the report of 1909-10, in addition to an excellent abstract of Soreau's "Etat actuel et avenir de l'Aviation."‡ In the Reports for 1910-11 and 1911-12 there is nothing; in the Report for 1912-13 there are two or three interesting communications, mainly due to the staff of the National Physical Laboratory, notably memoranda 77, 78, and 79. No. 77 (L. Bairstow, Melville Jones, and A. W. H. Thompson) is, in the main, an examination and extension of existing theory following the methods initiated by Dr. Bryan; No. 78 (L. Bairstow and L. A. MacLachlan), mainly relating to the determination of the various coefficients required for the application of Dr. Bryan's method of treatment. No. 79 (L. Bairstow), dealing with the more detailed application of the same method. These communications are conspicuous by the fact that their authors appear to be really *au courant* with the previous literature of the subject.

The work that has been done on the Continent on the sub-



FIG. 37.

ject of stability does not in sum amount to much, moreover it frequently appears to suggest complete ignorance of what has been done in this country; in this particular matter it would seem that the Continent has become insular and our island cosmopolitan. For example, we find the work of

* G. H. Bryan, "Stability in Aviation." Macmillan & Co. [illegible]
† Vol. II., "Aerodonetics." Constable & Co., 1908.
‡ Mémoires Société des Ingénieurs Civils de France.

Georges de Bathezat*, described by Mr. Painleve as "the first to give an exact and complete discussion of the stability of the aeroplane"; and when we examine the work so described we find the subject not more than half dealt with, and at that in so ineffective a manner that scarcely one of the conclusions can be regarded seriously. R. Knoller† and Reiszner,‡ though interesting, do not materially advance the subject. R. Soreau deals with the subject of longitudinal

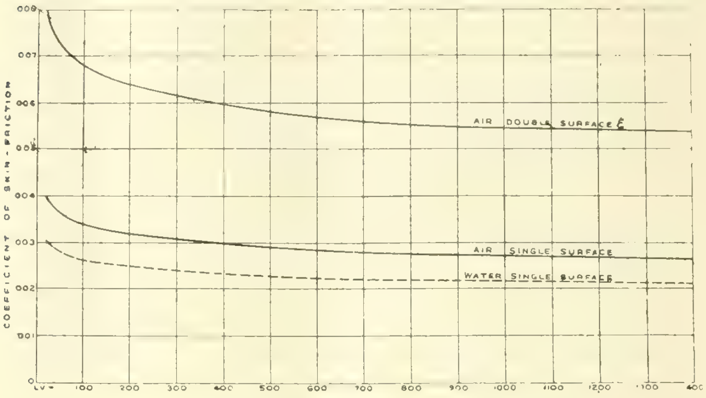


FIG. 38A.

stability under two distinct headings, *equilibrium* and *stability*; so far as the former is concerned his conclusions as formulated will be found in their entirety published by me in 1897, with the rationale clearly set forth.§ Soreau, however, scarcely carries the matter as far as in my previous publication. Incidentally Soreau gives two propositions, *i.e.*, minimum tractive force, and minimum horse-power, which, except for differences of notation, appear to be identical with two propositions previously given by me in "Aerodynamics," 1907, sec. 164. When we come to the question of stability it will suffice to state here that his conclusions on the subject of longitudinal stability are gravely at fault; briefly, Soreau states that the moment of inertia must not be too small for fear of oscillations becoming too rapid, whereas the only oscillation of importance—my "phugoid oscillation"—is virtually independent for its period on the value of the moment of inertia. On the questions of lateral stability and directional stability, Soreau's views (as pointed out by Bryan) are entirely at fault; the whole question of asymmetric or rotative stability is lost sight of, and the fact that in directional stability the centre of gravity cannot be treated as a static pivot|| is ignored.

The work of Captain G. A. Crocco is of interest. In the main he follows established mathematical lines of treatment;

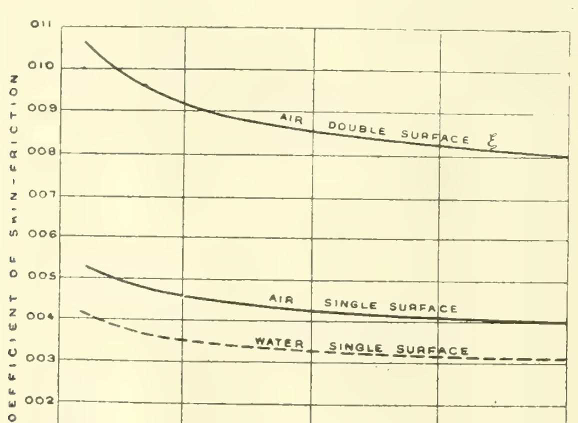


FIG. 38B.

I have made no attempt to follow his work in detail. Captain Crocco's conclusions on the whole appear to be far sounder than those of most continental writers: his work is evidently worth careful study.

The above may be taken as a brief summary of the existing literature of the subject. Excellent abstracts of the work of the foreign authors cited will be found in the appendices to the various reports of the Advisory Committee; excepting in the case of the French writers, which have been consulted in the original, I have relied on the abstracts in question for the summary here given.

In general the work has, in the past, been treated on too closely mathematical lines to be of immediate service to the engineer; in many cases the writers have clearly suffered from their want of appreciation of the real conditions. It is my deliberate opinion that there is very little room for useful work to-day on the subject of stability unless it be rigidly and directly supported by experimental work, and from our standpoint as engineers I think we may in the future confidently look to the excellent work being accomplished at the National Physical Laboratory, and at the Royal Aircraft Factory, to keep us in touch with that which is essential in this important branch of the subject.

APPENDIX I.

The subject of skin friction where air is concerned has been one of considerable controversy. The quantities to be

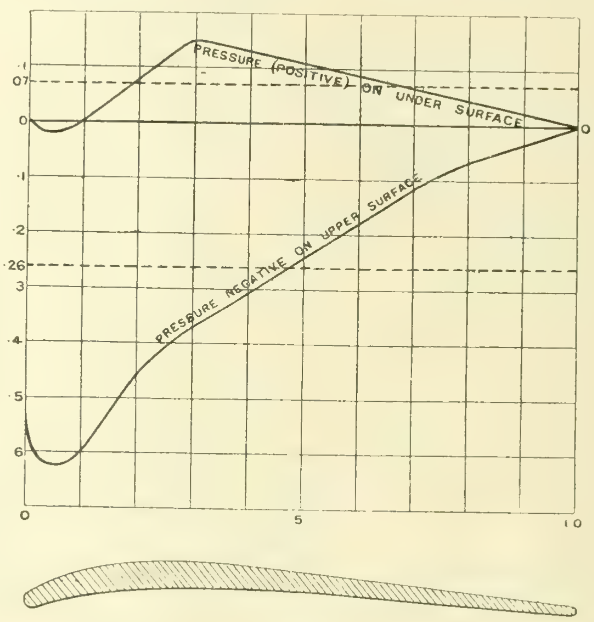


FIG. 39.

measured are so small and the apparatus employed until recent years has been so insensitive that until the work of Zahm in 1904 very little was known on the subject. Langley, in his "Experiments in Aerodynamics," 1891, asserted skin friction to be a negligible factor in its relation to flight. Dines about the same date expressed the same view; in my "Aerial Flight," Vol. I., which appeared in 1907 (not at that time aware of the work that had been done by Zahm), I published some determinations of skin friction and attacked Langley's views, pointing out that skin friction is one of the controlling factors in the economics of flight. I also introduced the practice of expressing skin friction as a coefficient representing the resistance of a thin lamina in tangential motion in terms of its resistance at 90°; the coefficient so expressed is the *double surface* coefficient, and in my work is represented by the symbol ξ. In the greater part of my experimental work planes or laminæ of mica were employed of but a few square inches area; the largest area used by him in any of his determinations was approximately $\frac{1}{2}$ sq. ft. Now it is well established that the coefficient of skin friction in a plane of small area is sensibly greater than in one of large area, consequently my values were on the whole considerably higher than those of experimenters working to a larger scale; however, the following passage may be cited as the summary of experiments made with planes of about $\frac{1}{2}$ sq. ft. area and of smooth surface: "It is therefore to be concluded that for a well-varnished surface or for polished metal, under the con-

* "Etude de la Stabilité de l'Aeroplane." Dunod, Paris, 1911.
† "Über Langstabilität der Drachenflugzeuge," 1911.
‡ "Einige Bemerkungen zur Seitenstabilität der Drachenflieger," 1912.
§ Patent Specification 3608, 1897, or compare also "Aerial Flight," Vol. II., page 353.
|| Compare "Aerial Flight," Vol. II., §§ 95 to 100; also Bryan, "Stability in Aviation," Chapter VII.

ditions of experiment, the effective value of ξ is approximately 0·009 with a probable error of less than 10 per cent., plus or minus."* According to the best estimate that can be made to-day the actual value of the double-surface coefficient under the conditions of the experiment in question should be 0·0081, showing an error of precisely the 10 per cent. which I allowed myself.

It has been frequently stated that my results were in entire disagreement with those of Zahm; sometimes those

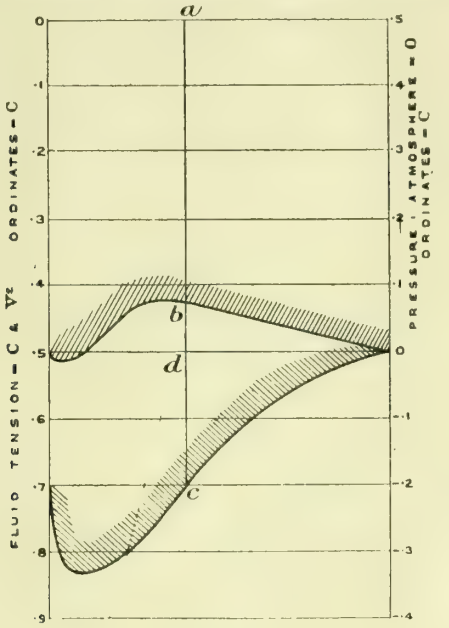


FIG. 40.

making this statement ignored my lower values and took his highest, which admittedly were too high; in other cases they read his double-surface coefficient as a single-surface coefficient, and so made his values twice as great as they really are.

In a communication to the Advisory Committee for Aeronautics (Memorandum No. 15, June, 1909), I pointed out that my own results and those of Zahm for air, and the results obtained many years ago by W. Froude for water, are in substantial agreement—in fact, in very close agreement—provided that they are put in their proper perspective, with due consideration to the laws of dynamic similarity.† The final conclusion given in the memorandum under discussion is expressed in graphic form in Figs. 38A and 38B, in which abscissæ represent the quantity LV (the product of the linear dimension‡ in feet by the velocity in feet per second), and in which ordinates represent the coefficient of skin friction. Three curves are shown; the upper curve is the double-surface coefficient for air, for which I employ the symbol ξ, the lower curve (solid line) is the single-surface coefficient (half the value of the former), the dotted curve is the coefficient for water. In Fig. 37, LV values may be read from 20 to 1,400. In Fig. 38 is given a graph for lower values.

It is a point not without interest that, for geometrically similar aerofoils, the weight sustained varies as $(LV)^2$ consequently for any given value of LV the weight is constant. In other words, as already shown, for least resistance $P = C\rho V^2$, where C is a constant whose value is round about 0·32, or if kL^2 represents the area, and W = weight,

$$W = 0{\cdot}32\, k\, \rho\, (LV)^2.$$

Therefore, assuming good design (max. lift/drift), and some definite value of aspect ratio (to fix the value of the constant k), the coefficient of skin friction is determined by the weight of the machine, and is the same whatever the designed velocity may be.

Skin friction has a habit of playing an elusive part in actual resistance phenomena, and the subject in practice is full of pitfalls. In the case of a plane moving edgewise, it may frequently happen that skin frictional resistance will virtually disappear, the leading edge of a plane such as used by the late Prof. Langley will by its bluffness set in motion a certain quantity of air, and this moving air subsequently washing the surfaces of the plane will reduce the skin-frictional resistance to something immeasurably small; as pointed out by me in discussing Langley's work, this was one of the causes that led him into error.

Another case where the coefficient of skin friction may be abnormally low is that of the inclined plane at a small angle of incidence, in "Aerial Flight," Vol. I., the matter is dealt with on page 264, article 182; it is pointed out that, as a deduction from gliding experiments made with the ballasted plane, and calculations based on same, the coefficient of skin friction is in effect less than ordinarily the case, and the explanation is offered that the upper surface of the plane being to a certain degree a "dead-water region" the coefficient may in this case be only that of the single surface. This conclusion has received striking confirmation in connection with some experimental work recently carried out at the National Physical Laboratory.

I consider it probable that in the case of the pterygoid aerofoil, that is to say, the aerofoil of arched section, such as shown at the foot of Fig. 39, the skin friction may in effect be abnormally high owing to the augmented velocity with which the air flows over the upper surface. This, speaking generally, is not altogether compensated by the lower velocity on the under side. The velocity of the air in the vicinity of the aerofoil can be deduced approximately from the ordinary laws of fluid motion from the local pressure. Now pressure curves have been made of several different sections of aerofoil by the National Physical Laboratory; the curve shown in Fig. 39 may be taken as roughly typical of the pressure graph for mid-section of any well-shaped aerofoil at or about its angle of least resistance, the ordinates downwards from the zero datum line being the negative pressures on the upper surface of the foil, and the ordinates measured upwards from the said datum line being the positive pressures on the under surface, in both cases measured above and below atmosphere. Plotting the same curve in Fig. 40 and taking a datum line corresponding to zero motion, ordinates will represent fluid tension (negative pressure) and the velocity at every point is represented by the square root of its ordinate; hence the skin friction will vary as the ordinate itself, and, referring to Fig. 40, the effective coefficient of skin friction will be greater than normal in the relation of the mean of the ordinates $a\,b\,a\,c$ to the ordinate $a\,d$. Referring again to Fig. 39, it may be observed that the mean pressure increase on the under face is approximately one-fourth of the mean pressure decrease on the upper face; taking this proportion as a basis, I give, in Fig. 41, graphs of the augmentation of the skin friction as a function of the aerofoil pressure constant; the normal

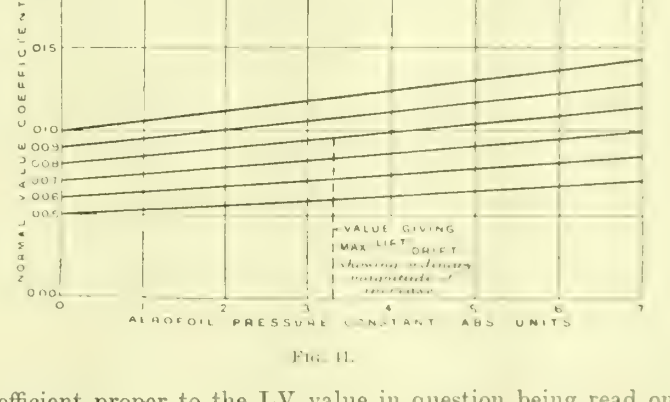


FIG. 41.

coefficient proper to the LV value in question being read on the ordinate corresponding to pressure constant = zero, on the left hand of the figure. In the case, for example, of the normal value of the coefficient being 0·008, it will be seen that for a pressure constant = 0·32 the augmented coefficient will be nearly 0·01.

We thus begin to obtain values approaching those that I have found to apply in connection with the theory of least

* "Aerial Flight," Vol. I., page 389.

† Compare memorandum cited, also addendum to same by Lord Rayleigh.

‡ Ordinarily the linear dimension, represented in the laws of dynamic similarity by L, presupposes geometrical similarity, *i.e.* geometrical form as an invariable. In the present usage, owing to the thinness of the layer of air affected, L may be taken as the linear dimension of the plane in the direction of motion.

resistance. If, in addition to the above, we allow an addition to represent *form resistance*, as has been found by Prandtl in the case of the ichthyoid body, and which is due to the degeneration of the stream-line system consequent on the appearance of the frictional wake, we might expect the effective direct resistance of the aerofoil expressed in terms of skin friction equivalent to a coefficient of 0·0175, which is in full and complete agreement with experience. The assumption here is that the proportion of the added *form resistance* bears the same ratio to the true skin friction, approximately 3 : 4, as commonly found in the case of the ichthyoid body.

FURNACE INJECTIONS TO PREVENT HANGINGS.

IN a recent issue of "The Iron Age" Mr. F. L. Grammer refers to the occasional very heavy loss through slips in blast-furnaces. Top slips are, he remarks, heaviest after longest hanging, partial or complete. If we can stop or shorten the hanging we can reduce the slip. This means reducing the loss of coke, ore, and stone, as well as increased safety to persons passing underneath; it also means fewer broken castings at the furnace top.

Let us consider the factors we believe favourable to top ore hanging in an iron blastfurnace. They are:—

Straight stack; represent its angle with plumb line by ... A
Narrow stack; represent its diameter by .... D
Fineness of ore particles; call the number to an inch ...... N
Softness of ore particles; call hardness by .... H
Richness of ore particles; call the units of iron .... U
High tension of gas; represented by .... t
Thick zone of carbon deposition—chiefly governed by temperature and gas composition and furnace height Z
Slow descent of charge, velocity in inches per minute V
Vertical thickness of ore charge, represented by C
Gas pressure due to velocity of rising gas at zone of carbon deposition .... P

There are other obvious influences such as the method of distribution of stock and specific gravity of fuel and ore. The above listed ones are the customary factors and will be considered exclusively. These influences may be put into a mathematical expression which will enable one to form a reasonable expectation and possibly a curve. Calling T the tendency to hang, then T varies directly and inversely as follows:—

$$T = \frac{N\,U\,t\,P\,C\,Z}{H\,V\,A\,D}$$

Of these influences the most potent seem to be N, H, A, and then P, Z, C, and possibly t. These latter are more flexible and more susceptible to change than the first three.

It is generally recognised that sustained hangings do not often occur on furnaces using coarse ore or even on magnetic concentrates unless very finely ground. Hangings occur less on short furnaces, and this is explained by the fact that such furnaces usually possess more tapered stacks, offering less foothold for arch or dome to spring from. Also such furnaces naturally have shallower zones of carbon deposition than the latter furnaces, where graduations of temperature occur through greater height.

We all know that carbon deposition is less marked on magnetic ores; it is also less marked on manganese ores. One can easily appreciate that the finer the ore the more surfaces there are offered on which the gas may react in this zone of change. It also holds that the finer the ore the smaller the interstices, and the more the carbon deposited fills such space, more completely binding the mass. A rich ore offers more iron than a lean one and so favours deposition. Smaller particles of ore increase the resistance to the passage of the blast and are themselves supported more by the rising gases, as in a jig. Tension of gas incident to back pressure tends to force gas around more particles of ore and so favours reaction. There are analogies in other chemical processes to warrant the reasonableness of the belief that high tension of gas accelerates carbon deposition from gas.

Among recognised cures for these evils is first slackening of the blast. This reduces the buoying effect of rising gases and the weight of stock moves the mass downward. Cold wind, by altering zones of heat and reaction and also by contraction, assists somewhat at times, but not so markedly as cold wind applied to cure a bosh hanging. Gas tension is reduced by cleansing flues and gas outlets, or making passage areas greater.

The furnaceman may modify the size of the charge somewhat. I have known the doubling of the size of a charge to increase blast pressure by 50 per cent. and more. These moves, however, have drawbacks. It is not always desirable to lower the temperature of the blast, and reducing wind volume decreases the output if it does nothing worse

In routine operations these represent the ordinary gamut of controls. The ore has to be used as it comes from the stock pile. An excessively fine portion being put in the bins, combined with the furnace driving slowly, is likely to be followed by a period of hanging, slips, or spitting at the top. Hanging reveals itself before the slip by blast pressure—stock gauge measurement or through records—or by the appearance of the gas at the stove or boiler burners and possibly by changes in gas composition revealed in composimeters such as Uehlings, &c.

However these explanations may be regarded, it is certainly true that the influences which affect the blast pressure and temperature and composition of rising gases at the zone of congestion will modify the strength of the arch. I therefore propose that furnace stacks should be equipped with devices to introduce steam, other gases, or water, say 15ft. to 25ft. below the stock line.

The action of these injections might be explosions in the case of water, or chilling in the case of gas or steam; but, if they occur below or at the side of the congestion, they should break the dome and re-establish the downward movement. The valve controlling should be accessible to men at the furnace front.

So far as I can learn this is a new idea and should prove of benefit in saving heat in ejected material as well as otherwise. Steam injection has, however, been tried at the tuyeres for bottom hangs, operating either through pressure or chilling. I am informed that at certain furnaces this has been found efficacious in urgent need.

THE CHECKING OF PYROMETERS.

A SOMEWHAT novel method for checking pyrometers has, according to "The Iron Age," been developed by The Henry Souther Engineering Company, of Hartford, Conn. This makes use of the critical points of blocks of steel of known quality and consists in heating a block of steel, the decalescence and recalescence points of which are known, to a temperature of 1,500° to 1,550° Fah., withdrawing it from the furnace and permitting it to cool in the air. The fire end of the pyrometer, which has been previously heated to redness, is inserted in a drilled hole in one end of the test block, and the drop in the temperature of the test block carefully observed. As the critical point on cooling, or the recalescence point, is reached, the needle will hang for an appreciable period before continuing again in its downward course. When this occurs, the observed temperature should correspond with the recalescence temperature furnished with each block. If the observed temperature does not agree with the proper recalescence point for the test block, it is, of course, apparent that the instrument is not reading correctly. The same temperatures for the decalescence and recalescence points will always be obtained, even though the blocks are reheated a number of times, and it is thus possible to use them over and over again for checking purposes without affecting the critical temperatures in any way. The test blocks are approximately 2¼in. diam. and 4½in. long, and it is stated that no special precautions are necessary during the cooling other than to avoid strong draughts.

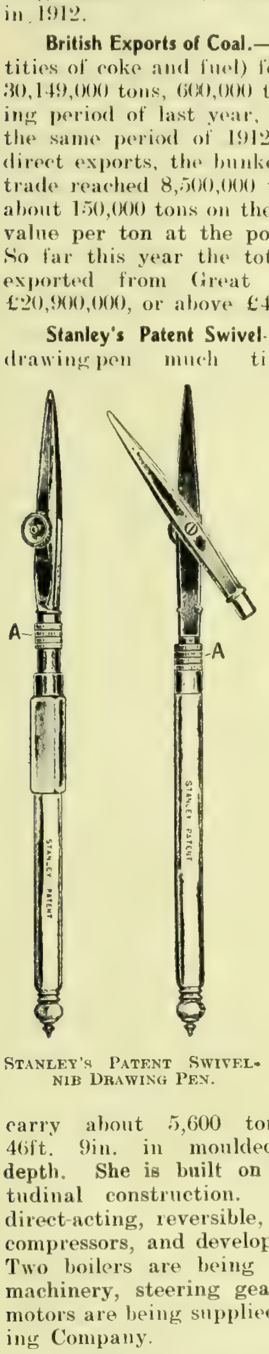
Explosion of Kitchen Boiler.—At a lodging-house at Jamestown, Inverkeithing, a boiler in the kitchen exploded on the 1st inst., causing injury to five men. Some men who had arrived off their night-shift duty at Rosyth were engaged cooking a meal when the explosion occurred. As a result of the explosion the boiler was dislodged and the apartment was shattered. It is supposed that the explosion was due to one of the water pipes entering the boiler becoming choked.

INDUSTRIAL AND TRADE NOTES.

Petroleum Output of Japan in 1913.—H.M. Commercial Attaché at Yokohama reports that the output of crude petroleum in Japan in 1913 amounted to 8,752,500 cases (of 8 Imperial gallons), as compared with 7,336,900 cases in 1912, an increase of 19 per cent. The chief contributor to the 1913 output was the district of Niigata ken with 8,260,145 cases, as compared with 7,129,600 cases in 1912.

British Exports of Coal.—The export of coal (with the small quantities of coke and fuel) for the first five months of this year were 30,149,000 tons, 600,000 tons below the figures for the corresponding period of last year, but nearly 9,000,000 tons more than in the same period of 1912—the strike year. In addition to the direct exports, the bunker coal shipped for vessels in the foreign trade reached 8,500,000 tons for the five months—an increase of about 150,000 tons on the same period of last year. The declared value per ton at the ports was a little lower than a year ago. So far this year the total value of coal, with coke and fuel, exported from Great Britain reaches the high figure of £20,900,000, or above £4,180,000 per month.

Stanley's Patent Swivel-nib Drawing Pen.—In the ordinary type of drawing pen much time is spent in cleaning the nib and in adjusting it, after refilling, to the required thickness of line. To overcome these objections Messrs. W. F. Stanley & Co., Ltd., the well-known manufacturers of drawing and surveying instruments, of 286, High Holborn, London, W.C., have recently introduced the pen illustrated herewith, in which the nibs can be instantly opened out for cleaning and afterwards replaced without interfering in any way with the original adjustment of the thickness of line. In construction the lower nib is swivelled upon a central screw, and when the pen is in use this is held in position by the ring A. To open for cleaning it is only necessary to slide back the ring and open out the nib as shown in the right-hand illustration; after which the nib and ring are replaced, which automatically readjusts the pen to its original setting.



STANLEY'S PATENT SWIVEL-NIB DRAWING PEN.

New Motor Ship.—Sir W. G. Armstrong, Whitworth, & Co., recently launched from their Walker-on-Tyne shipyard the twin-screw motor cargo vessel "Abelia," which they have built for the Flower Motor Ship Company, of London. The vessel, which will carry about 5,600 tons deadweight, is 350ft. in length, 46ft. 9in. in moulded breadth, and 27ft. in moulded depth. She is built on the Isherwood principle of longitudinal construction. She will have twin motors of the direct-acting, reversible, two-cycle type, with scavenging and air compressors, and developing 1,200 b.h.p. at 135 revs. per minute. Two boilers are being fitted for supplying steam for deck machinery, steering gear, and electric light. The propelling motors are being supplied by the Wallsend Slipway and Engineering Company.

Employment in the Engineering Trades.—The Board of Trade Labour Gazette states that employment in May was on the whole good. There was no further decline in the pig iron and steel trades, but in shipbuilding employment, although still good, showed some falling off. There was also a seasonal decline in coal mining. The engineering and tinplate trades continued to be well employed. Compared with a year ago, employment showed a decline in the principal trades. The coalmining, engineering, and shipbuilding trades were not so fully employed, and there was a marked decline in the pig iron and iron and steel. The changes in rates of wages affected 177,000 workpeople, of whom 17,000 received an increase of £1,700 a week and 160,000 sustained a decrease of £4,300 a week, the net result being a decrease of £2,600 per week. The number of new disputes in May was 140, and the total number of workpeople involved in all disputes in progress was 76,779, compared with 211,211 in the previous month.

Colliery Managers and Legislation.—In the course of some remarks recently made at the annual dinner of the National Association of Colliery Managers, Prof. Louis stated that there was no class of men who had been so singled out for legislation of all kinds as had the colliery manager. He had to bear a weight of legislation, of orders, and of regulations, and he had not time to learn the regulations before he was startled with a fresh batch from the Home Office. He was convinced that what they really required was not more regulations, but fewer regulations more exactly carried out. He did not think he could remember a serious colliery accident, the cause of which was properly traced without it being shown that that accident was due to an infraction of regulations—regulations such as were accepted in regular colliery practice. They wanted to strengthen the colliery manager's hands, so that he could enforce better discipline, and make it possible for him to insist upon regulations being carried out as they should be. Few regulations well carried out were worth the reams of regulations they now had to struggle with. The Government, he added, had paid the colliery managers a stupendous compliment. The Government had recognised that colliery management required men of such exceptional attainments and capabilities that it had raised the standard of examinations very considerably.

The Proposed 48-hours Week in the Engineering Trades.—In the June report of the Amalgamated Society of Engineers Mr. Brownlie, chairman of the Executive Council, gives an account of the two conferences which took place in May with the Federated Engineering Employers on the question of the 48 hours week. At the first of the meetings the following memorandum was agreed upon: "The representatives of the employers have considered the further arguments placed before them to-day by the representatives of the unions, and while they do not see that any further reason has been adduced for a reduction of hours beyond what was advanced in 1897, they are prepared to go into the subject further with a view to consulting their constituents again, on the understanding that the representatives of the unions will explain: (1) What security they can offer to the employers that a reduction of hours will not result in a reduction of output. (2) How a working week of reduced hours could be arranged with regard to overtime, night shift, continuous working, &c. For the purpose of going into this matter this conference stands adjourned." At the second meeting Mr. Brownlie contended in answer to these questions that historical experience of the ten-hour and nine-hour movements proved beyond doubt that notwithstanding the reduction in hours from 12 to 10 per day, and from ten to nine, the output was in no case diminished, but considerably increased. He quoted authorities to prove that the experience of the "home" manufacturer was not peculiar to this country, but applied to the whole civilised world, and gave instances of the output under eight hours being equal to that of nine, in consequence of men working in harmony with a national law. "To say that the employers were convinced by our arguments would be," Mr. Brownlie adds, "to take liberties with the English language." A spirited discussion followed, in which most of those who were present took part, with the result that the employers informed us that they would have to report to their respective associations, and would give their answer by the end of next month.

METAL QUOTATIONS.

TUESDAY, JUNE 16TH.

Aluminium ingot	86/– per cwt.
,, wire, according to sizes, &c. ......from	107/4 ,,
,, sheets ,, ,, ,,	112/– ,,
Antimony	£26/5/– to £28/–/– per ton.
Brass, rolled	$7\frac{1}{4}$d. per lb.
,, tubes (brazed)	$9\frac{5}{8}$d. ,,
,, ,, (solid drawn)	$7\frac{7}{8}$d. ,,
,, ,, wire	$7\frac{1}{8}$d. ,,
Copper, Standard	£61/12/6 per ton.
Iron, Cleveland	$51/1\frac{1}{2}$,,
,, Scotch	$57/1\frac{1}{2}$,,
Lead, English	£20/2/6 ,,
,, Foreign (soft)	£19/15/– ,,
Mica (in original cases), small	6d. to 3/– per lb.
,, ,, ,, medium	3/6 to 6/– ,,
,, ,, ,, large	7/6 to 11/– ,,
Quicksilver	£7/–/– per bottle
Silver	$25\frac{15}{16}$d. per oz.
Spelter	£21/7/6 per ton.
Tin, block	£136/10/– per ton.
Tin plates, I.C.	12/– per box
Zinc sheets (Silesian)	£24/10/– per ton
,, (Stettin; Vieille Montagne)	£24/12/6 ,,

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1912.

Change speed gearing and differential for motor cars. Mason. 27542

1913.

Decarburising metals. Bucher. 4667.
Ignition and starting systems for internal-combustion engines. Langner. 7232.
Lifting hook. Mawle & Wass. 8652.
Revolving cylinder internal combustion engines. Romaszko. 9677.
Means for locking nuts or bolts. Wade. 11773.
Combustion of combustible mixtures. McCourt, and Bonecourt Surface Combustion, Ltd. 11956.
Furnaces or other heating apparatus. McCourt, and Bonecourt Surface Combustion, Ltd. 11957.
Generation of steam, feed-water heating, and the heating of liquids generally. McCourt, and Bonecourt Surface Combustion, Ltd. 11958.
Rotary well boring apparatus. Mackenzie. 11968.
Air compressors. British Thomson Houston Company. 11996.
Reversing gear. Appleyard & Sales. 12117.
Carburetters for internal combustion engines. Watson & Duncan. 12123.
Variable-speed driving mechanism. Wade. 12167.
Treatment of tin ores. Wade. 12267.
Governing mechanism for engines. British Thomson Houston Company. 12477.
Roller boring drills. Hughes. 12560.
Revolving cylinder internal combustion engines. West. 12589.
Perforating transmission belts. Eaves. 12590.
Carburetters for internal combustion engines. Clark & Goddard. 12620.
Fluid flow meters. British Thomson Houston Company. 12663.
Carburetters for internal combustion engines. Binks & Binks. 12690.
Centrifugal pumps. Siemens Schuckertwerke Ges. 12738.
Asbestos metallic packing for steam engines. Howard. 12763.
Cams. Allegemeine Elektricitats Ges. 13108.
Boilers or evaporators. Catt. 13188.
Winding or haulage machinery. Gill. 13798.
Boring and screw cutting machine. Sauzade & Abry. 14216.
Furnaces. Atterbury & Matthews. 14862.
Valve mechanism for steam engines. Sensini. 15004.
Rope pulleys. Frood. 15211.
Process of reducing ore to metal. McLarty. 16277.
Hot tube igniters for internal combustion engines. Duffett and Smith. 17091.
Liquid meters. Kent. 17106.
Furnaces for heating steam boilers by means of combustible gases or vapours. Cousin. 17515.
Furnaces. Thomas. 17672.
Combustible mixtures for internal-combustion engines. Heyl. 18417.
Centrifugal pumps. Siemens Schuckertwerke Ges. 18572.
Chain grate furnaces. Bennis. 18637.
Driving and reversing gear for engine shafting. Ferguson and Ferguson. 19063.
Casting machines. Campbell. 19353.
Apparatus for producing water gas. Choury. 19363.
Carburetting apparatus for internal combustion engines. Lloyd. 19591.
Vices. Vauthrin. 19665.
Toothed gearing. British Thomson-Houston Company. 19937.
Apparatus for heating or cooling fluids. Watson & Billetop. 19970.
Steam valve gear for pumps and compressors. Brzezinski. 20359.
Worm geared hoisting machinery. Herbert Morris, Ltd., and Butterworth. 21167.
Turret lathes. Herbert & Vernon. 21636.
Lubricating devices for use upon internal combustion engines. Pearson. 22279.
Means for supporting and guiding blow-pipes for welding and cutting metals. L'Oxyhydrique Internationale Soc. Anon. 22628.
Process of casting ingots of metals and alloys, and apparatus therefor. Durville. 23719.
Means for stopping railway trains independently of drivers. Bassett. 23894.
Cocks and valves. Napper. 23912.
Controlling devices for fluid pumps in internal combustion engines. Rundlöf. 23947.
Variable speed motion transmission mechanism. Stresau and Fahn. 24299.
Stuffing box packing. Cook. 24613.
Headstocks of electrically-driven lathes. Kienzle. 24686.
Carburetters for use with internal-combustion engines. Soc. Les Fils de A. Leduc & Cie. 25199.
Starting mechanism for explosion motors. Fillettaz. 26391.
Valves for steam or water. Clayton & Taylor. 26434.
Wrenches. Vacarezza. 27145.
Train dispatching and signalling systems. Simmen. 27474.
Gas producers. Sahlin. 27888.
Liquid fuel spraying devices. Hamill. 28352.
Heat-diffusing devices for the smoke tubes of steam generators. Pielock. 28374.
Fuel injecting devices for internal combustion engines. Pasel. 28497.
Cylinders for internal-combustion engines. Grunwald. 29005.
Roller bearings. Modler. 29716.
Rotary valves for internal combustion engines. Hallett. 29823.
Self acting grinding and polishing machine. Offermann. 30028.

1914

Recording speedometers. Knopf & Knopf. 756.
Carburetter for internal combustion motors. Beghin. 1102.
Frictional change speed gearing. Lindley. 1500.
Heat engines. Godoy. 1872.
Fluid pressure braking apparatus. Turner & Donovan. 2805.
Thermostatic control apparatus. Malone. 3998.
Method of and apparatus for determining the density of gases. Bomhard & König. 4628.
Operation of turbo compressors or pumps. Akt. Ges. Brown, Boveri, & Cie. 5042.
Safety nut-locks. Ercinas. 5061.
Regenerative coke ovens. Carl Still and Wilke. 6036.
Cranes. Lake, and Lake & Elliot, Ltd. 6230.
Pneumatic hammers. Pullen. 8331.
Attachment of wire ropes to the cappels of colliery cages. Butterley Company, and Drabble. 9682.

ELECTRICAL, 1913.

Electric heaters. Mann. 11993.
Telephone systems. Automatic Telephone Manufacturing Company. 12035.
Incandescent electric lamps. Harrison. 12054.
Arc lamps. Ayrton. 12082.
Electrical selectors. Hodgkinson. 12100.
Fittings for metallic conduit systems for housing electrical conductors. Simplex Conduits, Ltd., and Waterhouse. 12115.
Telephone systems. Automatic Telephone Manufacturing Company. 12162.
Manufacture of electric cables. Beaver & Claremont. 13602.
Electric motor control systems. British Thomson-Houston Company. 14796.
Junction boxes for electric circuits. Walker. 14848.
Electrical heating units and resistance coils. Campbell. 15014.
Electrical switches. Fahn & Hutton. 17275.
Electric cut-outs. Murray. 17345.
Printing telegraph apparatus. Cardwell. 17439.
Telephone transmission systems. Western Electric Company. 18018.
Mechanism for producing a step by step motion by electrical means. Evershed & Vignoles, Ltd., and Needham. 28234.

1914.

Brush-holder and plug contact for use with magneto-electric ignition apparatus. Unterberg & Helmle. 3832.
Alternating electric current machines having bar winding. Allmanna Svenska Elektriska Aktiebolaget. 8565.
Starting and synchronising of rotary converters. Siemens Schuckertwerke Ges. 9225.

Fire Prevention.—The International Fire Service Council held an Executive meeting in London on June 15th, 16th, and 17th. The meeting was held at the invitation of the British Fire Prevention Committee, and the principal items under consideration were the preparation of an International Fire Dictionary, *i.e.*, a dictionary of fire-technical terms in three languages, and the arrangements for a conference on certain fire-service and fire-preventive subjects to be held at Copenhagen in 1915.

The Mechanical Engineer.
AN ILLUSTRATED WEEKLY JOURNAL Vol. 33, No. 857

Edited by
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Telegrams: "Scientific," Manchester.
Telephone No. 6655 City.

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Steam Turbine Design.

In the development of epoch-making inventions it often happens that the crux of the mechanical difficulties centres round some little detail that seldom comes within the ken of the outside public, although only too prominent to the actual designer or constructor, who has the trouble to face and all the anxiety that it means. In this respect the evolution of the steam turbine has followed pretty much the lines of experience in other directions. The blades seem an insignificant detail, and so they are viewed in relation to the whole machine, but their shape, construction, and attachment are all important, and the amount of ingenuity that has been expended in working out the problems associated with them is known only to those who make a study of patent records. It is no exaggeration to say that they out-number far and away all other patents in connection with steam turbines combined. As regards both material and construction there has been a considerable amount of evolution. The blades have to work in a current of steam of considerable velocity, and it not infrequently happens that the steam is laden with corrosive moisture or with foreign particles carried over from the boiler by priming. Centrifugal stresses have, of course, to be considered, but more important than this is the tendency of the blades to vibrate in the steam current, and the shrouding and other means of bracing the outer ends of the blades is not, as is commonly supposed, adopted with a view to imparting strength, as to reduce the tendency to vibrate, which it does mainly by raising the natural period, and thus diminishing the amplitude and with it, of course, the periodic stress. With the two main classes of turbines, viz., the impulse and the reaction, there is, of course, a difference in the type of blading required, the one requiring a relatively heavy blade section and the other a light one.

Although the strain due to centrifugal force is independent of this, inasmuch as it is a function of the density of the material, there is naturally considerably more risk involved in the event of a blade breaking away in the case of the heavier blade, and this possibility has exercised considerable influence on the methods of construction and attachment that have been adopted from time to time. Equally as much attention has been paid to the material of turbine blades as to their construction, and the efforts to secure high wearing power, with tenacity and ductility, have led to some special troubles in the use of cold drawn bars which could not well have been anticipated, and which were discussed in the course of Prof. Heyn's recent paper before the Institute of Metals. In the case he alluded to the material was of a high-grade nickel steel, and analysis and experience of its behaviour in other directions would not have suggested that it contained the seeds of trouble, and yet, after use, mysterious cracks began to make their appearance on the convex side of the crescent-shaped blade section. Careful investigation of the internal strains in the blade by the methods suggested by Messrs. Heyn and Bauer finally disclosed the cause of the trouble, and also suggested the method by which it could be avoided, but this was only arrived at after prolonged research, and is but typical of the equally laborious investigations that have been necessary in many other directions before the degree of perfection now embodied in this apparently insignificant but vitally important turbine detail could be acquired, and which it was necessary to attain before the growth in size, which has been such a conspicuous feature of turbine progress during the last few years, was possible.

The startling character of this growth is hardly realised. It was in 1894 that the future possibilities of turbines were suggested by the performances of the "Turbina," with its 2,000 h.p., developed by three motors running at 3,000 revs. per minute. Its effect was phenomenal, not only in marine but also in land practice, and led to a convergence of inventive talent on steam-turbine problems that has caused this type of prime mover not only to forge ahead of the reciprocating engine as regards economy, where large sizes are concerned, but in the course of 20 years to develop a size of unit which is stupendous. Some particulars of the latest and largest that are being laid down by the Philadelphia Electric Company were given in our last issue, but there can be no harm in this connection in repeating them. The unit, which is of the Curtis type, will have a capacity of no less than 35,000 kw., or, roughly, 47,000 h.p. It is difficult for the layman to form an adequate conception of such a motor, but some idea of its power may be inferred from the fact that it practically represents the total power required for 30 Lancashire cotton mills with about 100,000 spindles each.

LARGE HUMPHREY PUMPS FOR THE EGYPTIAN GOVERNMENT.

AN installation of Humphrey pumps has been ordered by the Ministry of Public Works of the Egyptian Government for the drainage of Lake Mareotis, at Mex, near Alexandria. When completed, this plant will be one of the largest pumping installations in the world, and will consist of 18 enormous pumps each capable of delivering 100,000,000 gallons per day through a lift of 20ft. The present order includes the first ten of these pumps, together with the necessary gas producer plant, Venturi water meters, travelling cranes, locomotive weighbridge, regulating gates and screens, and a complete gas-driven electric light and power installation.

The great size of the pumps may be judged from the fact that each unit is to be capable of delivering between two and three times that delivered by each large Humphrey pump unit installed at the Metropolitan Water Board's pumping station at Chingford. (See *The Mechanical Engineer*, January 9th, 1914, page 19 ante.) It will be recalled that the large pumps at Chingford, which were started in operation by their Majesties the King and Queen, in March of 1913, had an output of 40,000,000 gallons per day each. The pumps comprised in the present contract have been designed with the aid of the valuable experience obtained with the Chingford station, and include many notable improvements, although operating on the same cycle which has proved so successful at Chingford. The following approximate dimensions of the pumps for Mex will be of interest.

The maximum internal diameter of the combustion chamber will be 8ft. 8in., and its height about 14ft. The water valve-box will be 8ft. 8in. diameter and 7ft. high, and will be fitted with 100 valves of the hinge type, specially designed to enable any valve to close upon an obstruction, such as a piece of wood, without throwing undue strain on the hinges. The design is such that on the next stroke, when the obstruction has been removed by the rush of water, the valve will automatically readjust its position and close fairly upon its seat. This type of valve is a result of careful experiment, and has proved itself thoroughly satisfactory under test.

All the main castings will be of steel, and will be carried upon a cast steel bend, which connects to the play-pipe. This bend will be in two parts, making up the 118·5° required to connect with the inclined play-pipe. At Chingford the bend had an angle of 90°, and connected to a horizontal play-pipe, which in turn connected through a second 90° bend to a vertical conical water tower. At Mex, however, there will be only one bend, and the play-pipe is sloped upwards so as to deliver the water at the required elevation in the discharge basin. In order to reduce the velocity of the water at the exit, the play-pipe ends with a long conical portion giving a 12ft. diameter outlet. Not only does a sloping play-pipe eliminate one of the bends and give rise to a simpler construction, but it has the additional advantage that the vertical components of the forces due to momentum of the moving masses of water in the combustion chamber portion and play-pipe portion, respectively, are balanced.

The pumps will be started by forcing into the combustion chamber a mixture of gas and air, which is exploded by means of the usual sparking plug and switch, so as to give rise to the first oscillation, after which the working becomes automatic. Compressors capable of rapidly charging the pumps for this purpose and having separate cylinders for air and gas are included in the contract. Five of the pumps will be made by Messrs. Wm. Beardmore & Co., Ltd., of Glasgow, and five by Messrs. The Tecnomasio Italiano Brown Boveri, at Milan.

The anthracite gas plant capable of gasifying 44 tons per day will be of the self-vaporising type, and will be supplied by the Power Gas Corporation, Ltd. There will be nine producers, one of which will be a spare. The producers will be of the luted type. The gas from the collecting main will pass through two large gas-cooling towers, and then through dry scrubbers into a gas holder of 10,000 cub. ft. capacity, which, besides forming a mixing chamber for the gas will be used for accurately measuring the gas during the official trials of the plant, although for ordinary purposes the gas will be measured through a rotary meter. The plant will be complete with all auxiliaries, and special care has been taken that the plant shall be suitable for operation under the climatic conditions of Egypt.

The plant for electric power and lighting will comprise two gas engines each for 180 b.h.p. normal load of the two-cylinder horizontal type, running at 190 revs. per minute, and direct coupled to 120 kw. generators. The current will be supplied at 220 to 230 volts, and the plant will be complete with generator, power, and distribution switchboard panels. The lighting will be partly by arc lamps, partly by incandescent lamps, and the capacity of the plant is such that one unit will normally run the whole of the electrically-driven auxiliaries both at the producer plant and at the

main pump house. As this plant has to start operation in order to supply current to the large overhead travelling crane, and for working the centrifugal drainage pumps during excavation, it will be supplied with a 200 h.p. suction gas producer plant for temporary use, until the main plant is at work.

There will be two Venturi meters supplied by Messrs. George Kent, Ltd., each arranged to measure the water delivered from one or more pumps up to a total of five. These meters will be of square section, and 12ft. by 12ft. in the throat. Continuous recording apparatus and counters will be fitted to show the rate of pumping and the quantity of water delivered, and will be electrically connected to the recording instruments placed in the pump house. The meters are guaranteed to be accurate within 1¼ per cent. Except that the throat diameters will be lined with gun-metal, to ensure smooth and accurate stream lines, they will be mostly constructed of ⅜in. steel plates bolted to rolled steel joists, and jointed with lead strips. The meters will be partly supported in the natural rock as excavated, and partly by concrete walls.

There will be a railway weighbridge placed at the entrance to the sidings for the main installation, having a capacity of 60,000 kilos., and made sufficiently strong to take a locomotive up to 75 tons. It will be of the patent extension type manufactured by Henry Pooley & Sons, Ltd., and will carry a ticket printing steelyard. The weighbridge will be a combination of two self-contained machines, one weighing up to 40,000 kilos, and the other up to 20,000 kilos, and the overall length will be 42ft. The electric crane in the pump house will be capable of lifting up to 30 tons, and will have separate motors for the two lifting speeds and for longitudinal and transverse motions. The span will be about 35ft., and the crane will be built and supplied by Messrs. Jos. Booth and Bros., Ltd., Rodley.

There are other items included in the installation which need not be mentioned in this preliminary notice, but it should be stated that the whole of the work will be carried out under the supervision of the well-known firm of Messrs. Harper Bros. & Co., who are the consulting engineers to the Egyptian Government. They have prepared the specification and plans, and have designed the handsome buildings which will become a landmark in the neighbourhood of Alexandria.

SURFACE COMBUSTION FOR BOILER HEATING.

AN article on this subject by O. Dobbelstein in Glückauf, April 4th, 1914, and translated in the Proceedings of the American Society of Mechanical Engineers, is based on the work of the German commission on coke ovens, which, in connection with the Dortmund Association for the Inspection of Boilers, has carried out a series of tests on surface combustion boilers, at which the inventors, Prof. W. Bone and R. Schnabel, were represented. The tests are prefaced by a brief description of the surface combustion boiler, and improvements which the German manufacturers are proposing to make in them. One of such improvements is the construction of a more condensed type of machine, containing in itself a preheater and superheater, the latter being heated by a mixture of air and gas, burned in a loosely thrown fireproof mass, as shown in Figs. 1 and 2, the gases of combustion combining with the boiler flue gases and passing out through the preheater *v*. Instead of sensitive gas cocks pipes of a cross-section practically equal to those of the fire tubes are used, which the gas enters laterally, and the air from the rear. Not the gas admission but that of the air of combustion is regulated by means of ring valves set in the rear part of the tubes. The gases come through the main pipe *z*, and divide in front of the boiler through four horizontally-placed side-by-side branches with small cross-section. These branch pipes pass between the extension of the fire tubes and supply with gas each one of the two fire tubes. The lowest branch pipe is an exception, however, since only the second lowest row of fire tubes (see Fig. 3) is connected with it. The lower five fire tubes, *aa*, have no supply of gas and air mixture, but are heated by exhaust gas coming through pipe a_2 from the separately-heated superheater. In addition there are provided a smaller number of fire tubes, probably about 60, having a larger cross-section, and being about 3 m. long. This arrangement is provided for the case when hot feed water is already available.

On the Hanover mine the boiler is heated by coke-oven gas, having a heating value of about 4,000 W.E (7,600 B.T.U.), previously passed through the benzol separating plant, but not free from hydrogen sulphide nor cyanogen. After about three weeks of operation it was found that the fireclay filling in the front end pipes, on account of the high temperature prevailing, was partly melted and partly broken up. It was also found that the output of the boiler, which was initially about 64 kg./sq. m. of heating surface, had decreased considerably because the porous mass in the fire tubes of the preheater became clogged up, partly through deposits and partly owing to sulphurous formations, so that the exhaust notwithstanding a larger consumption of power could not supply a sufficient amount of gas and air mixture. This led to renewal of the porous mass both in the fire tubes of the boiler and those of the preheater, after which the first real series of tests had been started. Several of these tests quoted in the article may be considered only as preliminary, since during the performance adjustments of the gas cocks and even alterations in the arrangements were made.

The results of tests during some of the days were remarkable: The first day, during an 8-hour test, an output of 61·7 kg./sq. m. of the fire tube surface was obtained with considerable variation of the gas pressure at the beginning of

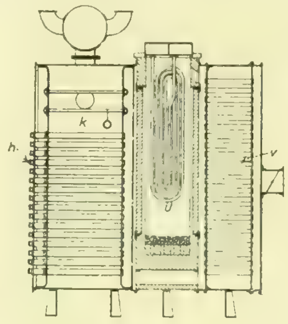


FIG. 1.

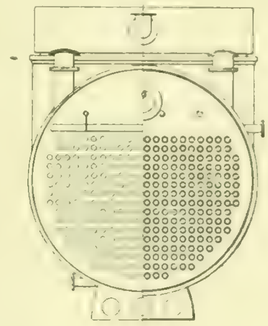


FIG. 2.

the test. The next day when this inconvenience was eliminated, the output rose to 66 kg./sq. m. The efficiency of the boiler was 93·3 per cent., and that of the preheater 3·9 per cent. If one takes the steam consumption of the electrically-driven exhaust fan, including all losses, as 10 kg. per horse-power hour, the total efficiency, including the preheater, would be about 89 per cent. with a moisture in the steam of about 2·5 per cent. average. These outputs would represent an important advance if they could be maintained for regular operation, which, the article states, is not yet possible. After 14 days' run the residues in the fire tubes of the preheater, owing to the clogging of the porous mass, had already increased to such an extent that the boiler had to be shut down in order to clean the fire tubes. It is now intended to take out the filling from the tubes of the preheater entirely and then establish the fall of efficiency. After several months of operation, the tests will be repeated in order to establish whether a further fall of efficiency occurs owing to the decomposition of the fireclay filling in the fire tubes of the boiler.

After three months of operation the boiler and preheater have been opened in order to see if there was any scale formation, and to take out the fireclay from the fire tubes. It was found that during this run of the boiler, estimated at about three months, in the front end of the fire tubes in the boiler a thin, hard layer of scale was formed, which in the rear ends of the pipes reached a thickness of 4 to 5 mm. The copper pipes of the preheater were strongly attacked, so that they had to be replaced by new pipes. The attacking of the pipes was due to the fact that when the gases of combustion were cooled down in the preheater to about 90° to 110° C. (194° to 230° Fah.), the sulphurous acid had an opportunity to unite with water and thus form sulphuric acid, which naturally strongly attacked the copper of the pipes. The analysis has shown that in the mass taken out from the pipes there was ·57 per cent. copper sulphate and 10 per cent. iron sulphate. Therefore, the cooling down of the gases of combustion to the temperatures of 90° to 110° C. (194° to 230°

Fah.) is to be rejected for operating considerations, especially as the gain in heat is only from 2 to 3 per cent., while the loss through the increased power combustion of the exhaust practically reduces to nothing whatever is gained by reduction of the temperature to so low a level.

The copper pipes have been replaced by cast-iron pipes, which was done especially because the use of the more expensive material did not appear to secure any corresponding advantage. The fire tubes of the boiler were filled with new fireclay mass, and new tests made. It must be borne in mind, however, that the gas pressure could not be maintained at the same level as in the second test, and as a result both the gas combustion and boiler output were about 5 per cent. below that of the former test. With coke-oven gas firing in this type of boilers, with numerous fire tubes in regular operation, one cannot hope to obtain more than 60 kg. of steam per hour per 1 sq. m. of the heating surface, since the available gas pressure is not usually more than 100 mm. (4in.) of water. Whether special apparatus to increase the gas pressure would prove to be economical or advisable remains as yet to be seen.

Here, as in all systems of gas firings, it is important to maintain as uniform a gas pressure as possible, since only in this case the admission of air can be maintained, so as to have the combustion preceded by the slightest possible excess of air. In this connection the fireproof filling of the pipes may be improved, even supposing that as it stands it could withstand operation for a length of time at the high temperature used. Owing to the irregular form of the separate pieces it is extremely difficult to make the filling so that the resistance in all of the pipes shall be equal. The Berlin-Anhalt Machine Company is therefore working on the preparation of a special uniform filling made up of pieces of refractory material of the same size. This will make it possible to place filling in such a manner as to maintain the resistance practically uniform in all the pipes, while the total resistance will be materially reduced, and this will lead to a reduction in the power consumption of the exhauster, and raise the efficiency of the plant. These tests have further shown that for ordinary metallurgical practice the construction of the boiler with numerous fire tubes is not suitable since they require quite a large amount of attendance. The above-mentioned concern is therefore endeavouring to reduce the number of tubes in their new boilers, and it is considered possible that later on ordinary fire tube boilers can be converted into surface combustion boilers. This would materially increase their output, and, further, the conversion of a fire tube boiler into a surface combustion boiler would eliminate the objection made to the Bone boiler in that its water space is too small, and that it has too low a reserve of steam.

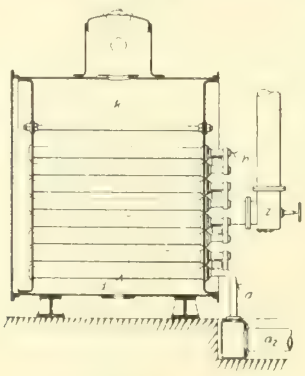


Fig. 3.

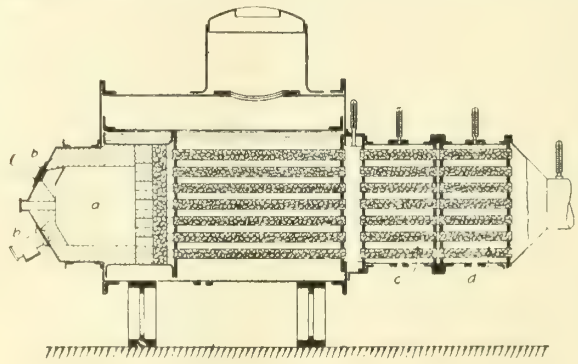


Fig. 4.

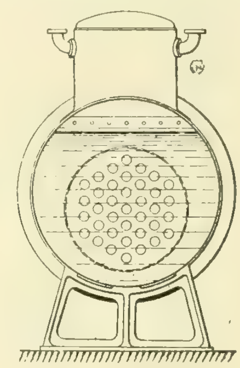


Fig. 5.

The tests described also included tests on the application of tar oil in surface combustion boilers, for which purpose the experimental boiler shown in Figs. 4 and 5 has been used. It was designed to work at 12 atmosphere gauge pressure, and had a diameter of 1·3 m., and a length of 1·7 m., provided with 37 fire tubes of 76·5 mm. inside diameter, thus constituting a total heating surface of 12 sq. m. Immediately connected with the boiler there is a preheater, *c*, also enclosing fire tubes, and supplemented by a second preheater, *d*, of the same construction, the installation of which was required because a single preheater utilised the heat of the flue gas insufficiently; in front of the firebox and partly inside it has been placed a combustion chamber, *a*, lined with refractory material and connected with the firebox of the boiler by means of slots in its refractory jacket. Over the boiler is located a wooden shed, on the roof of which is placed the tar oil supply tank, from which the oil flows automatically into the boiler after being preheated by exhaust steam to about 90° C. (194° Fah.), to distribute itself into three nozzles, *b*, set in the front wall of the combustion chamber. The electrically-driven fan provides the air of combustion, the pressure of which is sufficient to atomise the tar oil and to overcome the resistance of the fire tubes.

Previous to each test the boiler was maintained in operation for about two hours, this time being sufficient, on account of the small content and consequent rapid heating, to bring the boiler into its normal state of operation. The tar oil and feed water were weighed, the feed water being also checked by means of a Siemens water meter; the readings of pressure, temperature, and power consumption at the fan were taken at regular intervals of 15 minutes, the gas analysis being as far as possible taken also at the same intervals. On the whole the tests have shown that on forced runs with surface combustion boilers and tar oil as fuel, outputs up to 120 kg. per hour can be obtained. It is doubtful, however, that the boiler can be relied on to run regularly at such a rate of output, since both after the first and after the third tests it was found that the front tube wall leaked, even though it appeared that the fireclay wall built in front of it would protect it from the immediate action of the fire. On the other hand, it must be remembered that the cooling of the boiler was very rapid, because after the end of the test the oil firing was cut off immediately.

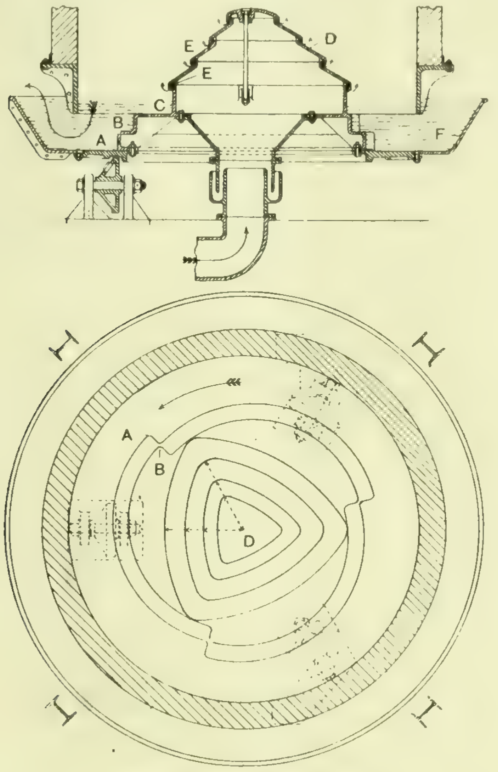
It appears, therefore, that this type of boiler is not suitable for continuous operation when there are many rolled-in connections in the zone of the highest temperatures. The Berlin-Anhalt Machine Company has, therefore, designed a different type of boiler in which the tar oil comes in through a single nozzle, together with the air of combustion supplied by a special fan. The combustion chamber consists of a single cylinder of refractory material, placed in the fire tube. The hot gases enter through the fireclay grating into the third part of the fire tube, which is filled with large pieces of fireclay. It is expected that this type will be more suitable for continuous operation than the one shown in Figs. 4 and 5. The author concluded that neither the coke-oven gas-fired boiler nor that using tar oil was suitable for continuous operation, though it was possible that a different design would obviate the present difficulties.

IMPROVEMENTS IN GAS PRODUCERS.

Mr. Axel Sahlin, of 52, Rue du Congres, Brussels, has recently patented the arrangement of grate and its blast tuyeres for gas producers shown in the accompanying cuts, for which it is claimed (1) a regular removal of ash and clinker from the interior of the producer, (2) an equalised distribution of the entering blast over the entire area of the bed of fuel, and (3) a continual but gentle agitation of the partly consumed fuel on its downward course as it passes the annular blast openings.

The grate is constructed with a base or scraper formed in two or more steps, A B, each being divided into three or more cam-shaped arms or wings, as shown in the plan view, the points of which are equidistant from each other. The

lower cams or scrapers have a more extended radius than the superimposed scrapers, but the points of both are approximately in line or coincident with each other. Above these scrapers is placed a feeder, C, formed as an equilateral triangle with convex sides, the angular extremities of which are located on the same circle as the innermost corners of the upper set of cams or scrapers, and a little to the rear of the corners. This last-named section is surmounted by a series of inclined covers, D, also formed on bases of equilateral triangles with convex sides, and having their angular extremities in line with one another. These upper triangular covers constitute the tuyeres, air and steam being blown through narrow slits or interstices E in same into the surrounding fuel. The two first-mentioned scrapers, the triangular feeder, and the triangular-shaped covers comprising the grate are all concentric with each other, and are propelled, together with the ashpan, F, by worm gear at a slow speed, so as to revolve in a direction shown by the arrow in the plan view, which will give all the moving parts a tendency to push the ashes and coal lying in front of them away from the centre of the producer. As each cam or scraper passes around the ashpan F (the inner end preceding the outer end) it creates behind it a space or void



GRATE FOR GAS PRODUCERS.

which is immediately filled again with the ashes from the strata immediately above it. The ash so deposited is then carried onwards by the following or succeeding scraper in like manner.

The rotation of the scrapers A and B forces the ashes outwardly below the wall of the producer, where they gradually rise, and finally escape over the inclined sides of the revolving ashpan F. This may be facilitated by the introduction of a fixed scoop or shovel at any convenient point on the outside wall of the producer, which directs the flow of the ashes to any point most convenient for their discharge. The convexity of the triangular sides of the covers D gives an undulatory as well as a gyratory movement to the fuel contents of the producer, especially in the lower strata, where the fuel is becoming spent, and where the increased admission of air is necessary to complete combustion. The triangular covers which constitute the grate may be so proportioned that the sheet of blast issuing from the lowest tuyeres will at the nearest point to the centre be equidistant with the extreme point of the sheet of blast issuing from the tuyeres immediately above as shown by the dotted lines in the plan view. This second section bears the same relation to the one above it, which in turn has a similar relation to the one above that. In this way the tuyeres distribute the blast equally over the interior of the producer.

SOME RECENT IMPROVEMENTS IN CASE-HARDENING PRACTICE.*

BY HENRY L. HEATHCOTE, B.SC.

(*Concluded from page 575.*)

Permeability to Heat.—Having found a composition far more permanent in its properties than any then in current use, the author proceeded to investigate the factors concerned in permeability to heat. Most commercial mixtures consist of or contain a large proportion of small particles which it seems reasonable to expect will block up all the interstices and prevent the free passage of heat, for it has been shown that the heat conductivity of insulating materials depends chiefly on their air spaces. To test this point granular charcoal was employed, and two model case-hardening pots were made 5in. high, 3·7in. diam., and 0·04in. thick, made of sheet steel and welded together. One contained the charcoal under investigation, and the other was used empty. A thermometer bulb was placed at the centre of each pot and the apparatus placed in an oven at 180° C. Fig. 4 shows the rise of temperature with time. The curve on the left shows the temperature at the middle of the empty pot; those on the right, numbered 1, 2, 3, 4, refer to charcoal of various sizes, each containing approximately the same proportion of moisture and taken from the same sack (see Table V.):—

TABLE V.

No.	Weight of Contents.	Charcoal.	Pieces per Gramme.	Moisture lost at 110° C.
	Grammes			Per cent.
1	215	Would not pass through sieve 5 meshes per linear inch.	36	6.30
2	209	Passed through 6 but not through 7 meshes per linear inch.	130	6.17
3	215	Passed through 7 but not through 30 meshes per linear inch.	450	6.23
4	296	Passed through 30 meshes per linear inch.	—	6.03

Two striking points are brought out by these results: (1) The arrest of temperature at the centre at about 100° C. while moisture is being driven off. (2) The effect of size of grain, and particularly of dust, upon the duration of the arrest.

When the same samples were again heated the temperature rose much more quickly (see Fig. 5). The absence of any arrest is of course due to the moisture having been expelled during the previous tests. Needless to say, the temperature at the core of a hardening pot will not remain at 100° C. for nearly three hours if the heating is done in a

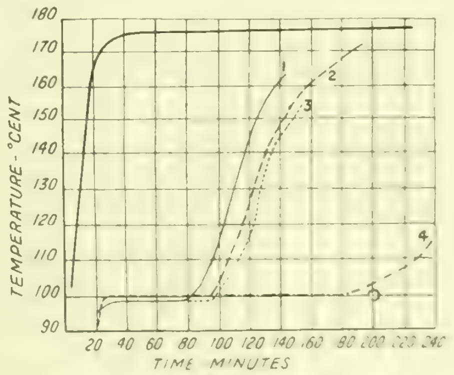


FIG. 4. RISE OF TEMPERATURE OF CHARCOAL OF VARIOUS SIZES CONTAINING ABOUT 6 PER CENT. MOISTURE.

red-hot muffle; but the author has observed that there is an arrest, and another when other volatile matter begins to be given off, when the model pots are filled with oily bone black and heated in red-hot lead at about 850° C.

A mixture which can be used over and over again possesses the great advantage that moisture, oil, and other volatile constituents have, for the most part, been already expelled by the previous heatings. This is illustrated by the results

* Paper read before the Iron and Steel Institute, May, 1914.

plotted in Fig. 6. The curve on the right refers to a mixture of bone black and bone dust; and the middle one to the soda ash and charcoal mixture, consisting of three parts used to one part not used, freed from all small particles and dust by means of a sieve with round holes, 0·08in. diam. The two mixtures were heated at the same time, the curve on the left showing the rise in temperature of a similar empty pot.

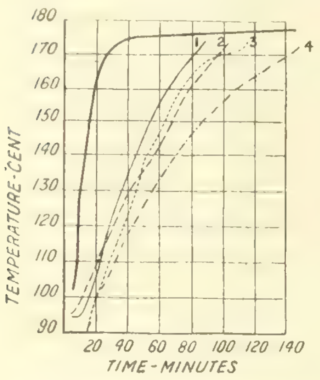


FIG. 5. RISE OF TEMPERATURE OF DRY CHARCOAL OF VARIOUS SIZES.

To see if these results represented anything of commercial importance the author carried out some tests in pots 10in. high by 10in. diam., with coarse and fine mixtures having the same composition. The same number and kind of articles were packed in each pot, and test pieces, 1½in. by ½in. square, were placed near the top and bottom and at the middle of the pot. The pots were then heated together for five hours, the maximum temperature being about 925° C. These test pieces were reheated to 760° C. and quenched in water to show the depth of the case. Table VI. represents the results:—

TABLE VI.

	Fine.	Coarse as No. 3.
	Inch	Inch
Top	0·025	0·045
	0·03	0·05
Middle	0·02	0·04
	0·025	0·04
Bottom	0·03	0·045
	0·03	0·05

The figures denote the depth of case.

In another test done on a commercial scale we compared the mixtures referred to in Fig. 6. The test pieces were placed at the middle only. The pots were 9in. high by 9in. diam., and heated for four hours side by side, the maximum temperature being about 925° C. One pair of test pieces was then reheated as in the previous comparison, and the other sectioned and examined microscopically. The results are given in Table VII.:—

TABLE VII.

One-third Bone Black, one-third Crushed Bone, one-third Spent Bone. Size as No. 3. Not free from dust.		Charcoal. Size as No. 2, impregnated with Soda Ash. Free from dust.	
	Inch		Inch
Hard	0·01	Hard	0·03
Soft	0·015	Soft	0·04

The figures denote the depth of case.

TABLE VIII.

	Carbon per cent.		Carbon per cent.		Carbon per cent.
Surface layer	1·050	11th layer	0·750	22nd layer	0·395
2nd layer	1·020	12th ,,	0·695	24th ,,	0·365
3rd ,,	1·015	13th ,,	0·655	26th ,,	0·330
4th ,,	1·010	14th ,,	0·630	28th ,,	0·315
5th ,,	1·000	15th ,,	0·595	30th ,,	0·305
6th ,,	0·950	16th ,,	0·585	32nd ,,	0·305
7th ,,	0·880	17th ,,	0·535	34th ,,	0·275
8th ,,	0·840	18th ,,	0·505	36th ,,	0·255
9th ,,	0·830	19th ,,	0·480	38th ,,	0·227
10th ,,	0·810	20th ,,	0·440	40th ,,	0·205

Composition of the Case.—Having secured a considerable improvement in both permanence and permeability to heat, it remained to ascertain whether this "composition" imparted a suitable percentage of carbon and gave uniform results from day to day. Mr. W. T. Flather has made a great number of determinations of carbon in the successive layers of the case, and was good enough to carburise some bars of Ubas steel in his standard pot, and under his standard conditions, but using the dust free charcoal impregnated with soda ash, three parts used to one part fresh already referred to. The results of the carbon determinations (made in the Research Laboratory) are to be found in Table VIII. The bars were ⅞in. diam. and 6in. long, and were carburised four hours at 925° C. Successive layers, 0·0025in. thick, were turned off all along, the end half inch being left on to avoid end effects. Some of the carbons were determined by combustion, and the others by the colour test, using the former as standards.

The even gradation of the carbon content from surface to core is noteworthy.

In a test on a commercial scale, extending over 29 days, test bars 1in. diam. were carburised along with ordinary work at 900° to 925° C., the mixture being replenished once or twice a week to make good the inevitable waste. The bars were cooled in the pots, and the surface layer turned off as above analysed:—

	Per cent. carbon.
New mixture	0·967
End of 1st day	0·909
End of 4th day	0·981
End of 29th day	1·06

The author considers 0·9 to 1·1 carbon satisfactory, and preferable to less than 0·9 per cent. The cementite does not appear to form laminæ unless the percentage of carbon is greater than 1·05; and for work that has to be ground a slight degree of supersaturation at the surface is considered necessary. Charred leather at 1,000° C. imparts about 1·3 per cent. carbon, at 925° C. about 1·2 per cent. carbon, and Guillet's composition (barium carbonate, 40 per cent.; wood charcoal, 60 per cent.) at 925° C. about 1·2 per cent.

These analyses disclose the average carbon content of the layer in question, but they do not give any evidence of uniformity. A priori it is quite possible that such large grains may produce local inequalities in the degree of carburisation. To test this point, the author has employed the colouring solution, also the scleroscope and sclerometer referred to later. Even when the case on 1in. bars of Ubas steel was not more than 0·012in. deep, the colour developed showed no indication whatever of local paucity of carbon. Here is a bar carburised in mixture made with No. 1 sized grains of charcoal (see Table V.). It is uniformly hard all over, even after grinding off the outside layers of the shallow case. Had there been lack of uniformity from this cause it would have made itself evident also in the micro-sections of rods done in the exhaustion tests. This uniformity doubtless connotes a gaseous agent for conveying and maintaining the supply of carburising agent. Bars 1in. diam. bound together, then carburised, separated, and quenched are quite

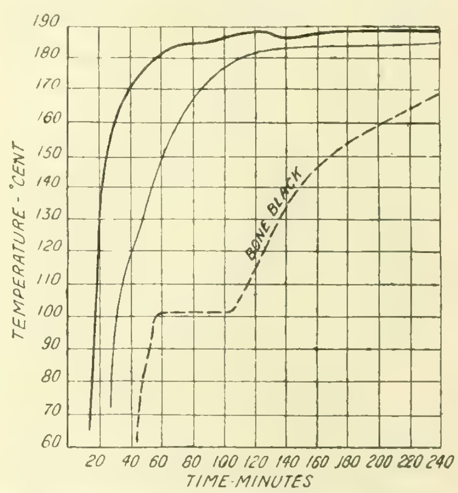


FIG. 6.—COMPARISON OF SODA ASH CHARCOAL MIXTURE AND BONE-BLACK BONE-DUST MIXTURE.

hard even where no particles of the mixture could possibly have touched the steel.

It will be readily understood therefore that a composition of this kind, replenished regularly with a small proportion of fresh mixture, is capable of giving very uniform results. On account of its low specific gravity, comparative freedom from dust, oil, and moisture, the heating-up period is a smaller proportion of the total time, so less judgment is

required in allowing for the size of pots, &c. The productivity of the hardening plant and staff is correspondingly increased, and the steel too is all the better for the shorter heating.

An Improvement in Tempering.—The use of hot tallow and lead for tempering is of course well known; but the application of an electric welder, which, the author believes, was originated by V. A. Holroyd, presents some novel and advantageous features. It is particularly useful for local softening or tempering (Fig. 7), and unlike tempering in tallow, the core of the article is left softer than the outside. This is specially advantageous for case-hardened articles. The operation is a very quick one, and the surface is left quite clean.

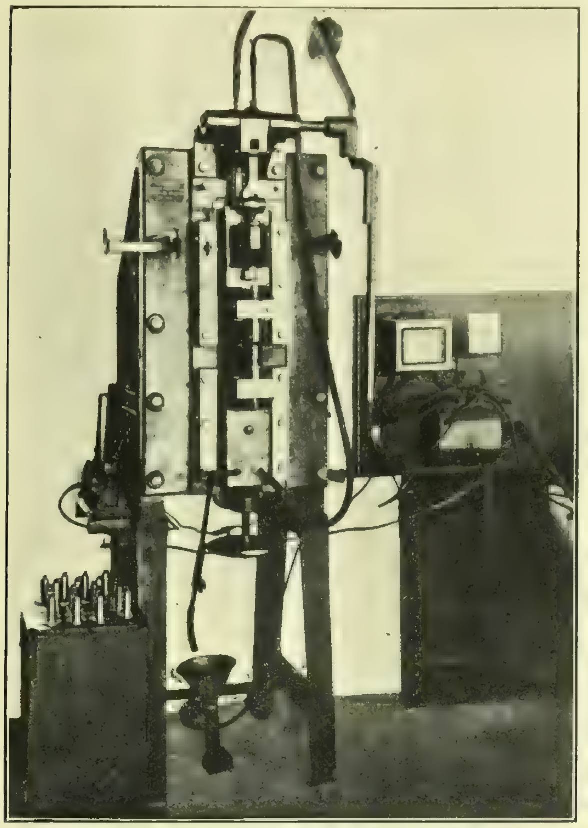


FIG. 7.—ELECTRIC WELDER ARRANGED FOR TEMPERING CASE-HARDENED ARTICLES.

Methods of Testing Hardness.—So far as the author is aware, very little work has been done to provide commercial means for testing the suitability of case-hardened articles. The practice of examining test pieces carburised, heat treated, and hardened along with each batch is of course sound as far as it goes. The Shore scleroscope and Brinell test have their spheres of usefulness. But still the file is the instrument most used, and perhaps rightly, for it does give an idea of the resistance the surface of the article offers to abrasion under pressure, which is what most articles are case-hardened to withstand. This and the Brinell test are, we believe, the instruments in commonest use for testing case-hardened work and test pieces.

For small articles a modified centre punch is suitable for rapidly getting a working idea as to whether the case is above the minimum permissible depth. It consists of an ordinary 6in. Brown and Sharpe automatic centre punch to which is fitted a screwed-on container for holding a $\frac{1}{8}$in. bicycle ball. The hard point is removed and the container screwed on in its place. The ball protrudes just sufficiently to prevent the container coming into contact with the article under test. This is very useful for large as well as small articles, and its readings appear to refer more to the case and less to the core than those obtained with a Brinell testing machine.

An Improved Sclerometer.—On account of the variable element in testing resistance to abrasion with a file by hand, the author sought to devise means for measuring the friction under a given load. A pair of "scissors" with files in place of shears was found to be cumbersome, and the weight of the article introduced variations according to the position the scissors were held in. Small flat articles can be placed on the top of a file, and the hardness gauged by raising one end of the file and observing the angle when the article slides.

This led to placing the article under the file so that its weight causes relative motion, which motion ceases (if not too rapid) when the frictional forces are great enough. This instrument (Fig. 8) is for testing round surfaces. A soft bar holds the top file up so that it makes an angle of about 70° with the bottom one. The actual angle is indicated by figures engraved on the slotted quadrant. A hard bar will not hold the file up until the angle falls to about 15° to 20°. A hardened and tempered bar gives readings between these angles according to the degree of temper.

Another form adapted to take larger articles is made with three [illegible] files, so that the outer two can be moved further apart at will (Fig. 9).

For concave surfaces such as the ball races of motor car bearings a different type (Fig. 10) is employed. The essential part of this is a short piece of round file which, with its two ends resting on the bearings, slides down one side, and is deflected as the bearing is rotated. The angle taken up depends on the hardness and consequent friction, and is measured on a graduated quadrant.

For flat surfaces a short file is mounted in a holder which slides along a smooth bar until friction arrests the motion (See Fig. 10.)

The readings, *cæteris paribus*, are within considerable limits independent of the diameter of the test object.

Let a = radius of test object = OA = OB,
l = $\frac{1}{2}$ length of upper file = CM.
α = angle between the files,
w = weight of object,
W = weight of upper file.

Consider the equilibrium of the test body.

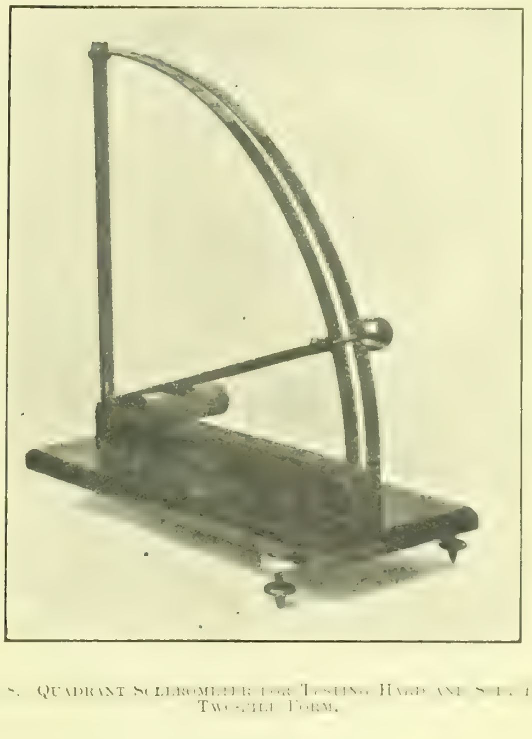


FIG. 8.—QUADRANT SCLEROMETER FOR TESTING HARD AND SOFT [illegible]. TWO-FILE FORM.

Resolving along CO (Fig. 11) we have:—

$$(F+F')\cos\frac{\alpha}{2} = (N+N'-w)\,.\,\sin\frac{\alpha}{2}.$$

$$\therefore \tan\frac{\alpha}{2} = \frac{F+F'}{N+N'-w}.$$

Taking moments about O we have:—

$$Fa = F'a.$$

$$\therefore F = F'.$$

Resolving vertically we have:—

$$N' = N\cos\alpha + F\sin\alpha + w.$$

Substituting we get :—

$$\tan\frac{\alpha}{2} = \frac{2F}{N(1+\cos\alpha)+F\sin\alpha}$$

Putting $\frac{F}{N} = \mu$, the coefficient of friction, we have—

$$\tan\frac{\alpha}{2} = \frac{2\mu}{1+\cos\alpha+\mu\sin\alpha},$$

which shows that the readings are independent of the weight and diameter of the test body provided the coefficient of friction does not vary with the diameter.

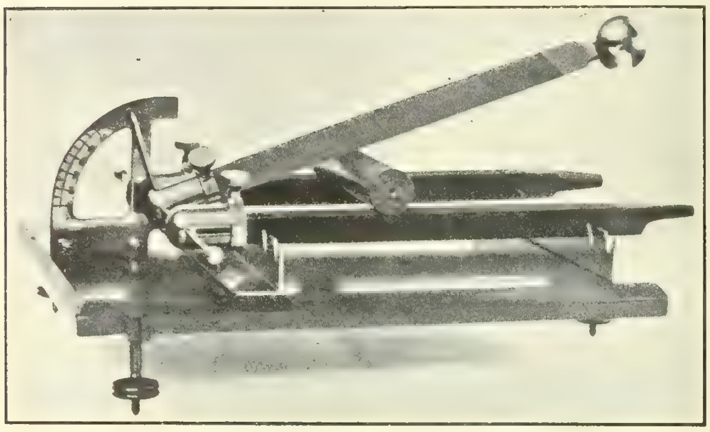


FIG. 9.—QUADRANT SCLEROMETER. ADJUSTABLE THREE-FILE FORM.

When used in the vertical position the investigation is somewhat different. Consider the equilibrium of the connected files in Fig. 12.

Resolving along CO we have :—

$$\pm(F+F')\cos\frac{\alpha}{2} = (N+N')\sin\frac{\alpha}{2} + 2W.$$

The sign of the first term depends on whether C moved down or up just previous to equilibrium.

By symmetry :—

$$F = F' \text{ and } N = N'.$$

Substituting we have :—

$$\pm F\cos\frac{\alpha}{2} = N\sin\frac{\alpha}{2} + W,$$

$$\text{or } \pm\mu\cos\frac{\alpha}{2} = \sin\frac{\alpha}{2} + \frac{W}{N},$$

$$\therefore \tan\frac{\alpha}{2} = \pm\mu - \frac{W}{N\cos\frac{\alpha}{2}}$$

Consider the equilibrium of one side.

Taking moments about C :—

$$W \cdot l\sin\frac{\alpha}{2} = N \cdot a\cot\frac{\alpha}{2},$$

$$\therefore N = \frac{Wl}{a} \cdot \sin\frac{\alpha}{2}\tan\frac{\alpha}{2} = \frac{Wl}{a} \cdot \frac{\sin^2\frac{\alpha}{2}}{\cos\frac{\alpha}{2}}$$

Substituting in the expression containing μ we have :—

$$\tan\frac{\alpha}{2} = \pm\mu - \frac{aW\cos\frac{\alpha}{2}}{Wl \cdot \sin^2\frac{\alpha}{2}\cos\frac{\alpha}{2}}.$$

Whence

$$\tan\frac{\alpha}{2} = \pm\mu - \frac{a}{l} \cdot \frac{1}{\sin^2\frac{\alpha}{2}}$$

In this case, therefore, we should expect the angle to be independent of the weight of the files and test body and to increase as its diameter decreased, the effect of the variation being less the longer the file. Experiment shows that the angle is slightly affected by variation in the diameter, but in the opposite direction to that indicated above. The results obtained with variously treated bars 1in. diam. are recorded in Table IX.

Both the quadrant sclerometer and Shore scleroscope give lower readings for smaller diameters. With the former the difference is greater for soft, and with the latter for hard bars. This is probably due to the file teeth in the one case, and the falling weight in the other, throwing up steeper "ramparts" round the depression when the surface is less convex.

TABLE IX.

	Treatment.	Quadrant Sclerometer.	Shore Scleroscope.
1in. Bars Ubas Steel.	As received	75°	28
	As received. Carburised 5 hours, cooled in pot	69°	29°
	As received. Carburised 5 hours, reheated to 760° C., quenched in water	20°	89°
	As received. Carburised 5 hours, reheated to 760° C., tempered 1 hour at 300° Fah.	28°	88
	As received. Carburised 5 hours, reheated to 760 C., tempered 1 hour at 400° Fah.	33°	82°
½in. Bars Ubas Steel.	As received	63°	27
	As received. Carburised 5 hours, cooled in pot	60	33°
	As received. Carburised 5 hours, reheated to 760° C., quenched in water	18°	76°
	As received. Carburised 5 hours, reheated to 760° C., tempered 1 hour at 300° Fah.	26°	71°
	As received. Carburised 5 hours, reheated to 760° C., tempered 1 hour at 400° Fah.	36°	70°

For commercial testing of hardened work and within wide limits the error due to varying diameter is negligible in the



FIG. 10.—QUADRANT SCLEROMETER FOR TESTING FLAT SURFACES.
Inset.—Quadrant Sclerometer for testing concave surfaces.

case of the quadrant sclerometer. That the instrument is very sensitive is shown by the way it detects slight degrees of tempering. Several are in regular use at both the Rudge-Whitworth Works, where they have to a large extent superseded the cruder hand test with ordinary files. They are

handy and quick, and capable of dealing with large quantities of work in a short time. Instead of files, carborundum or alundum sticks or pencils may be employed, but files give very good results and last many months without showing any errors due to wear, provided they are properly made and appropriately aged before use. Various standards have been adopted for different articles, and the angle should come between the specified limits in order to pass the viewer.

Production of Colours on Hardened Work to Facilitate Viewing.—Many articles, such as cups and cones, cannot be conveniently tested with a scleroscope or sclerometer on account of their

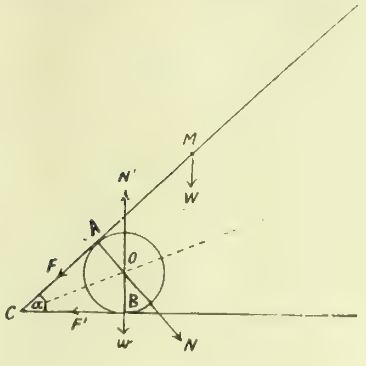


FIG. 11.

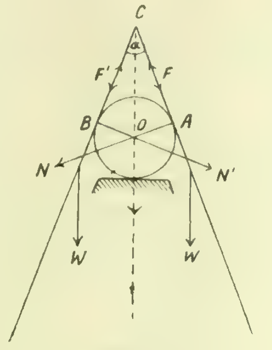


FIG. 12.

shape. Realising the need for some method which would enable articles of all sorts to be tested in bulk, the author turned his attention to the production of colours on hardened surfaces which would afford an indication of the nature of the steel composing such surfaces. The ordinary solutions employed by the metallographer are unsuitable for commercial application, some because of their inflammability, others because they will not flow evenly over a somewhat oily or greasy surface. A suitable solution which has been found to give satisfactory results consists of:—

Alcohol	1 litre.
Distilled water	1 ,,
Nitric acid, pure	100 cubic centimetres.

Articles ground or polished after hardening and immersed in this for ¼ to 1 minute are stained brown or light blue where the structure is martensitic; dark blue or dark grey where there is troostite; and hardly stained at all on ferrite or pearlite.

By treating hardened articles in this way, before viewing, inequalities are rendered visible and can readily be detected. The fact that the whole of the surface is tested, and not merely the parts touched by the file, sclerometer, or scleroscope is an enormous advantage for commercial purposes. The test reveals at once spots that have been splashed before quenching, and contain troostite, also superficial tempering due to a glazed surface on the grinding wheel or to excessive pressure. It does not appear to be possible to obtain a colorimetric scale of hardness in this way, but when a number of articles are dipped at the same time the eye readily detects those that have a different appearance, and all that is then necessary is to check the odd ones with a file or sclerometer. This test is also suitable for tools and complicated articles that cannot conveniently be tested with an instrument. It also shows the depth of case if a part is left on and ground away, and should prove useful for ascertaining whether an article has been properly tempered.

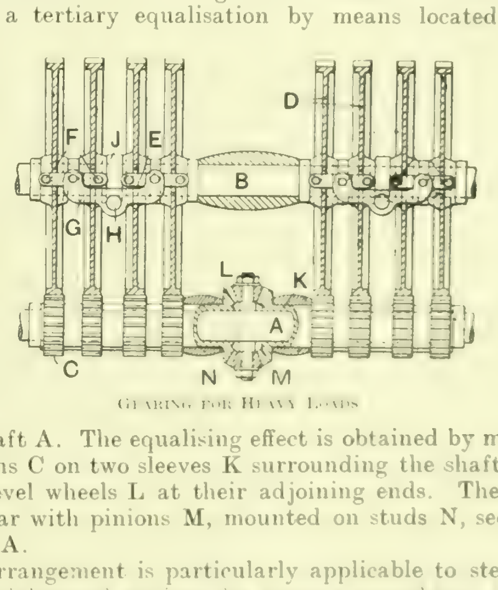
The swinging hammer is the outcome of another attempt to replace the variable muscular force of the tester by the constant force of gravity. Instead of a skilled viewer wielding a hammer we use a simple instrument, consisting of an ordinary hammer swinging on a support passing through a bushed hole in the handle. A heavy steel block carries the support and is arranged to admit various holders adapted for receiving, and if necessary clamping, the parts to be tested. It has been found very useful for testing small parts, such as the rollers of motor-cycle engine bearings, the blow being controlled by observing the angle on the graduated quadrant behind the hammer.

In bringing this paper to a close the author takes this opportunity of thanking the directors of Rudge Whitworth, Ltd., for permission to publish the information it contains.

GEARING FOR HEAVY LOADS.

ORDINARY gears used in the usual manner to transmit heavy loads have been unsuccessful. The lack of success may be attributed to a number of causes, one of which is that the load on the teeth of the gear wheel increases at a greater rate than the increase of size or wearing surface of the teeth. To transmit a heavy load with ordinary gears it would be necessary to make the gear faces enormously long, which is impossible, as the greatest width of the gear which can be used is limited for practical reasons. It is impossible to make two intermeshing gears of sufficient length of tooth face to carry the enormous load necessary in modern marine propulsion and for other heavy duty, and at the same time have them equally engage. So also it is impossible to use a number of gears rigidly keyed upon two shafts for the reason that there will be inequalities in alignment so the gears will not carry their true proportion of the load. To overcome these difficulties it has hitherto been proposed to mount a plurality of toothed or chain wheels on one shaft, and to connect them to each other and to the shaft by equalising devices, so that the tooth pressures are equally distributed. It has also been proposed, in connection with chain gearing, to employ two chains, which transmit power between pairs of chain wheels on the driving and driven shafts, the two chain wheels on each shaft being connected to one another and to the shaft by means of equalising devices to equalise the load. The equalising devices hitherto proposed have consisted of pivoted levers or bevel gear wheels, which permit of slight relative movement to distribute the load under transmission equally.

An arrangement has recently been designed and patented by Charles G. Curtis, 2, Rector Street, New York, U.S.A., in which the connection of the two shafts is made by means of spur gears, by using a plurality of gears on each shaft, and providing distributing means such as has hitherto been proposed on both shafts, so as to divide the load equally among the gears. One arrangement is shown in the accompanying illustration. The shafts connected by the gearing are indicated by A and B. The shaft A carries eight pinions, C, which mesh with eight gear wheels, D, mounted loosely on shaft B. The gear wheels D are connected together in pairs by primary equalisers E, consisting of bars which connect pivots F on the two wheels. The primary equalising bars of two adjacent pairs are connected together by secondary equalising bars G, which are pivoted to the primary equalising bars E, and also pivotally connected at H to sleeves J, secured to the shaft B. It will be observed that the primary equalising bars permit relative circumferential self-adjustment of the two gears which they connect; that the secondary equalising bars perform this office for the two pairs of gears which they connect. Within the limits of circumferential self-adjustment permitted by the equalisers, an equal distribution of the load between all the gears is effected. There is also provided a tertiary equalisation by means located on the



GEARING FOR HEAVY LOADS.

pinion shaft A. The equalising effect is obtained by mounting the pinions C on two sleeves K surrounding the shaft A, and having bevel wheels L at their adjoining ends. These bevel wheels gear with pinions M, mounted on studs N, secured to the shaft A.

The arrangement is particularly applicable to steam turbines or high speed engines for marine propulsion, in which the shaft speed is higher than the propeller or driven shaft speed, and in which the load to be transmitted is much larger than can be transmitted by ordinary gears.

THE OXY-ACETYLENE PROCESS OF WELDING.*

BY HENRY CAVE.

AUTOGENOUS welding is a general term given to welding when metal fuses. In the ordinary blacksmith's weld the metal does not fuse; it becomes plastic and is hammered together, but unless hammered no weld would be produced. Autogenous welding is carried out in several different ways, but as here referred to is by means of acetylene burned with oxygen. The use of oxygen with other combustible gases consisting of an oil gas similar to Pintsch gas, termed "liquid" or "Blau gas" in this country, hydrogen and a few others are sometimes used, but are not efficient owing to limitations of temperature. The process using acetylene necessarily makes very much the hottest flame, owing to the large amount of carbon in the composition of this gas.

This process is an indirect development of electricity. Shortly after the electric furnace was developed, the general use of acetylene was made possible, calcium carbide, from which acetylene is generated, being made in the electric furnace. In 1895, shortly after the development of calcium carbide, Le Chatelier, the French scientist, proposed this process, that is, that the burning of acetylene with pure oxygen would produce a very high temperature. It was not, however, until 1905 that an equipment came into this country for practical use in a factory. From that time there has been a gradual development in the equipment and a rapid development in the uses for the process.

The acetylene is produced in a generator direct from calcium carbide, the gas passing through a reducing valve and hose that connects with the torch. If a welding equipment is

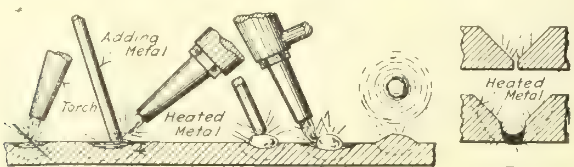


FIG. 1.—DIAGRAM SHOWING METHOD OF MAKING TYPICAL OXY-ACETYLENE WELD.

to be used for portable work or work of an intermittent nature, acetylene is obtained from a dissolved acetylene cylinder as a source of supply, instead of from a generator, the other parts of the equipment being the same. The dissolved cylinders are not merely empty cylinders into which the gas is compressed as is the case with the oxygen cylinders, but contain a porous material, generally asbestos, into which is poured acetone or a similar liquid; the acetone absorbs the gas and the liquid is held in suspension, thus filling the cylinder at all times, and in that way it is perfectly safe under a high pressure. The gas is drawn off through a hose, as is also the oxygen from the other tank, and both are brought together in the torch.

The source of the oxygen in a general way is a cylinder of compressed gas. In some cases the compression is very high, up to 1,800lbs. per square inch, which high compression is for the sake of economical conditions of transportation. But in some cases it is used in low-pressure cylinders (300lbs. per square inch) which are charged from generating equipment on the premises, or it may be generated and compressed directly into the service pipes by several different means. The chemical method of manufacture from chlorate of potash and manganese dioxide requires the cheapest equipment, but provides the most expensive gas, and is very little in use now. The electrolytic method of disassociating water into oxygen and hydrogen is coming very rapidly into use for large and small installations. Very large oxygen generating equipments have been installed for making oxygen from the atmosphere by the liquid air process, the oxygen being distilled off from the liquid air.

The torches used in both welding and cutting work are provided with tips for producing different sizes of flames in each torch. That is the same as changing the size of flame in a gaslight by removing a burner and replacing it with a larger or smaller one, the variation of flame being required for welding different weights of material. The tip is made of brass, there being one hole through the centre, the mixing arrangement where the oxygen and acetylene are mixed together in correct proportions being located at the inner end.

In addition to the use of this process for welding, another operation of interest because of its connection with the oxy-acetylene process and that it is carried out with practically the same equipment, is the cutting of steel by means of oxygen. Cast iron and non-ferrous metals cannot be cut by oxygen, steel, wrought iron, and cast steel being the only metals cut in this manner. I have known of considerable expense being undergone in attempts to cut cast iron, due to ignorance of this feature, the reason being the free carbon in the iron stops the penetration of the oxygen. The cutting torch differs from those used for welding in that the tips have more than one hole; the central hole supplies the pure oxygen for cutting and the two outside holes are heating flames, identical with those used for welding.

The process of cutting steel in this way is a development of the old school experiment of inserting the red-hot end of a clock spring into a jar of oxygen, in which the red-hot part of the clock spring began to glow and was gradually consumed, proving that steel would burn in an atmosphere of oxygen. The process is simply reversed in practice, in that the flame is applied to the piece of metal and a small spot heated, then the jet of oxygen is directed on that red-hot spot and the metal begins to burn; in burning it produces a slag of high temperature which, in flowing down the face of the part, is sufficient to heat the metal through a considerable depth (24in. has been cut) so that the oxygen can combine with it. Thus the action is progressive, one layer being consumed heats the next one. It is not possible, however, to extinguish the heating flame, as it is required to keep the molten slag fluid so that it will flow out of the cut; that is the only reason for keeping the combustion of the acetylene going while the cut is in progress after the first start is made.

This process of welding is not generally understood. There is a knack in making a strong weld, a knack that can be acquired only by the exercise of considerable judgment and practice. Fig. 1 shows the method of making a typical weld. The torch tip here carries a flame of 6,300° playing on the metal, and a pool of molten metal is first of all formed at A. The metal is heated up approximately, as indicated by the shaded portion. Upon that spot is deposited a drop of molten metal from the rod of adding metal B, the end being fused into the melted pool C. The drop is then fused still further so as thoroughly to adhere it to the piece to which it is being welded, by playing the flame around that drop, until it assumes a shape as at D. With a sharp corner such as at C, no satisfactory weld would be produced, because there would be a spot on each side which could not be welded, but by playing the flame around a thorough weld right across would be obtained. The condition is very similar to the use of soft solder. Those familiar with it never trust work where the edges of the solder are rounded, but realise when they spread out to a thin edge the union is satisfactory. A succession of drops is put on in that way. These drops overlap each other, so a thoroughly strong weld is produced.

At E, Fig. 1, is a condition where parts are to be welded of considerable thickness. It should be stated that owing to the high temperature of the oxy-acetylene flame, a weld can be made from $\frac{1}{8}$in. to $\frac{3}{16}$in. in thickness without preparing the parts, that is, without bevelling them out as shown at E. If it is a crack in a casting, it is chipped or ground out by means of some mechanical method, or if it is steel, it can be cut out by means of the oxygen jet and a groove formed. If it is attempted to make the weld from the outside without this groove, the metal would burn before its conductivity had time to convey the heat deep enough to make a weld of any depth.

With this process, the metal is first of all heated to red over a considerable area before any metal is added. The flame is then played at the bottom of the groove on the points of the prepared sections until they fuse together into one solid mass, and then additional metal is added. Thus the weld can be made completely through the parts. The additional metal is then built in and each drop fused to the side, producing a thoroughly homogeneous weld until the groove is filled up. This building up can be continued to any extent to reinforce the part at the weld or change its shape as desired.

The theory of the process of oxy-acetylene welding is shown in Fig. 2. A Davis-Bournonville high-pressure positive-mixture torch tip is shown at A. The acetylene,

* Abstract of paper read before the American Society of Mechanical Engineers.

C_2H_2 passes in at the side orifices indicated and is ignited. When it is lighted in air a reaction takes place as shown (two and one-half parts of oxygen uniting with one part of acetylene yield carbon dioxide and water) and the reaction produces a temperature about the same as ordinary illuminating gas (about 2,500° Fah.). The oxygen in this case is taken from the air; the fact that the air is only one-fifth oxygen is responsible for the fact that the gas has to spread out over a very large area to collect that one-fifth of oxygen, and also there is the four-fifths of nitrogen which is carrying the heat away needlessly. This heat is wasted and thus reduces the temperature of the flame. When the flame is burning, you will see that a considerable amount of unconsumed carbon is given off at the end of the flame, which shows that even then there is not sufficient oxygen for complete combustion.

When oxygen is supplied, from the cylinder or other source of supply of pure gas, passing in under pressure at the small opening indicated at the end of the tip and striking the acetylene which is also under pressure, at right angles, a thoroughly homogeneous mixture is produced, and when a mixture of one part of oxygen and one of acetylene is provided by the orifices, the reaction is as shown at B. (One part of oxygen uniting with one part of acetylene yields hydrogen and carbon monoxide.)

The high temperature of 6,300° Fah. is obtained in the bright cone immediately at the end of the tip. The hydrogen cannot burn in that high temperature zone as it cannot unite with the oxygen, because it is above the disassociation temperature of water. It therefore passes out to the long flame, which is called "the envelope," and burns to H_2O; neither can the carbon monoxide, the product of the first reaction, unite with the additional oxygen to produce carbon dioxide in the high temperature zone, and therefore this reaction must also take place in the envelope. The additional amount of oxygen is in both cases obtained directly from the air if a satisfactory design of torch is used.

The carburetting arrangement in the torch, which is generally at the base of the tip, corresponds to the carburetter of an automobile, and if it is not adequate or not of a good type, the mixture and reaction will not take place as given above. If too large a proportion of oxygen is supplied, this additional oxygen cannot possibly unite with a combustible element in the high temperature zone of this reaction because all the carbon is used up by one part of oxygen. Therefore the surplus must pass through to the envelope, and as shown at C, we have the reaction indicated (two parts of oxygen uniting with one part of acetylene yield hydrogen, carbon monoxide and a surplus of free oxygen).

Part of the surplus oxygen going to the envelope unites with either the hydrogen or the carbon monoxide and forms carbon dioxide or water vapour in the secondary reactions, so that a portion only of the oxygen required for these reactions is taken from the air instead of all of it; some of it is, in other words, taken from the source of supply, at a cost of 3½ cents per cubic foot (more or less, depending on conditions) instead of obtaining it from the air without cost, and that is obviously a very uneconomical condition.

If the means for bringing the oxygen and acetylene together are not such as will produce a vortex, and therefore cause all the molecules of oxygen to come in contact with the molecules of carbon in the acetylene, a certain proportion of the oxygen will pass out of the tip, and through the high temperature cone, unconsumed. Therefore to allow for this, a larger amount of oxygen must be supplied to obtain the normal adjustment of the flame which is distinguished by the clear outline of the inner cone. It can therefore be seen that this clear outline does not necessarily mean that the flame is neutral, as if the surplus oxygen is present as above, the flame must necessarily be oxidising. The normal or ocular adjustment, as it might be called, therefore, may indicate a proportion of oxygen to acetylene of one to one (1·12 to 1 is the nearest to this that has been obtained) or it may indicate as high as two of oxygen to one of acetylene, 1·8 to 1 being very common.

If too large a proportion of oxygen is supplied through the tip for the normal setting as given above, the flame is shortened and the colour is changed, D, as compared with B. The flame condition shown at E indicates too large a proportion of acetylene or a shortage of oxygen from the normal setting, the acetylene showing an extra or extended point on the bright welding flame. Those two extreme conditions are used by the operator to adjust his flame, but he can only adjust it within the limits of the mixing device. The tip, A and B, is shown because it is a simple representation of the "high pressure positive mixture" carburetting device, but has now been changed to the form shown at F, the principle of which, however, is the same. The tip seats in a cone and the oxygen passes through the central orifice and the acetylene through the radial orifices, striking together so that there is no question of a thoroughly molecular contact of the gases being produced before they pass out and are ignited.

Another type of torch which is shown diagrammatically at G is that in which the two gases are brought together by what is termed the injector principle, oxygen passing in and shooting straight through a chamber which contains acetylene either under several pounds pressure or under only a few ounces. The conditions are practically the same in both cases. The oxygen shoots through and the capillary attraction or "skin friction" of the oxygen draws in the acetylene and produces a condition in which there is pure oxygen in the centre and pure acetylene around the outside, with the mixture in a zone between the two as shown in section XY. It is well known that the injector is made just as smooth as

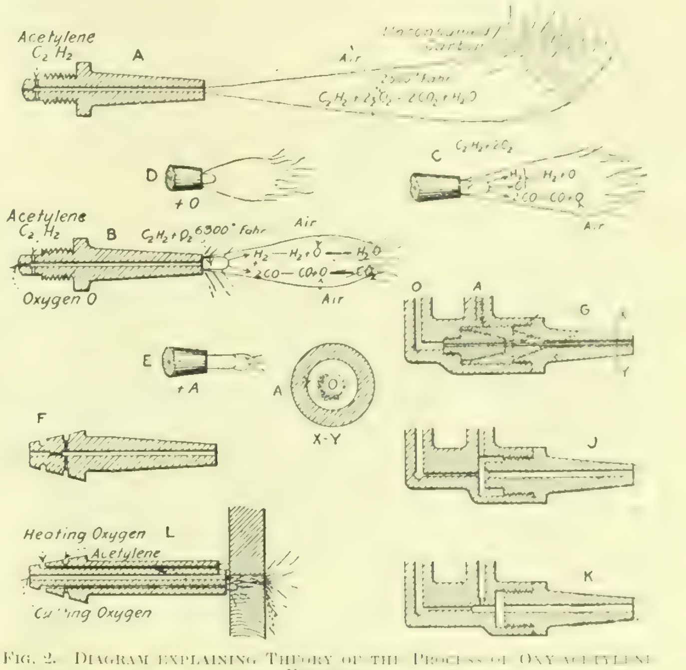


FIG. 2. DIAGRAM EXPLAINING THEORY OF THE PROCESS OF OXY-ACETYLENE WELDING.

possible inside, so as not to produce any vortex; also that an automobile carburetter will not work satisfactorily unless the gases are thoroughly mixed together. The same applies to a torch. This torch is made in various styles. Sometimes the injector cone is a narrow passage and sometimes quite a large area; there are frequently jogs or enlargements in the passage with the idea of producing mixing effects. All the gas, however, passes through the centre of them.

Another type of tip is shown at J. This differs only in detail from the previous one described, the principle being that of the injector, though without any cone, there being no control of the proportion of the two gases that pass in by orifices, such as are shown at A, B, and F, the size of the orifices in these tips being accurately determined for the various sizes of tips for the amount of gas required, thus ensuring the correct proportion at all times.

At K is shown another type in which there are passages which regulate the amount of gases passing through, but these are in the head of the torch instead of the tip. Therefore when a larger or smaller tip is inserted, the mixing passage remains the same, so that only one of the set of tips for that torch has orifices correctly proportioned

At L is a diagram representing the cutting operation. This torch tip has a central passage through which the jet of oxygen passes. It has a side passage which carries an ordinary heating flame, the cutting being in the direction of the arrow, so that flame heats the metal in advance. There is also a following flame which is just the same as that used

for welding, merely for the effect of keeping the slag fluid so that it will run out of the weld.

The process of oxy-acetylene welding and cutting is being used to a considerable extent for the repairing of steam boilers. The operator should be certified as to his ability to make a good, strong weld. The operator is frequently merely an unskilled "handy man" who has been instructed in the knack of making a strong weld, but has no knowledge of boiler structures or the strength of metals or their heat treatment, and therefore is not capable of judging the conditions under which welds should be made. This process of welding is developing a number of other lines of metal working. For instance, pressed steel is coming into use very largely everywhere it is possible to use it, but its use has been limited to what could be made in dies. Pressed work in connection with welding has no limits, because the parts can be made in sections and then welded together. Cast iron can be welded perfectly satisfactorily. The metal will be soft if the work is carried out by a skilled operator with an equipment that does not remove the free carbon by combustion with the surplus oxygen in the flame, and it can be made so soft that expensive milling cutters and other tools can be used on it without any fear of their being damaged.

Aluminium is an extremely difficult metal to weld, owing to several conditions. One is that it oxidises so rapidly; another is that it has practically no strength when it is a few hundred degrees in temperature. It has also high conductivity, so that a large portion of the piece is heated and the heat wasted. It has very high expansion and contraction. All these conditions make it an extremely difficult metal to handle; and yet it is possible to weld it.

What I believe to be the largest welding job that has ever been carried out and at the greatest saving, was carried out on the steel pipe line at Boulder Mountain in Colorado. The Colorado Power Company built this pipe line, using butt strap construction, which proved faulty. They tried all kinds of ways to correct the difficulty, but without avail. The trouble was that the water leaked out from between the butt straps, the water having a head of some 1,700ft., giving 825lbs. pressure at the base. The pipe was 4ft. diam. at the bottom and 1¾in. thick. A tremendous amount of water came out from these joints and it was threatening to wash away the foundations and destroy the whole structure. Something had to be done immediately. Half a million dollars had been put into the structure and the whole thing was being held up. Finally it was welded by the oxy-acetylene process, in the winter on the side of the mountain, in a temporary structure which was moved from one point to another. A V-groove was first cut so as to make a deep weld, with the cutting torch. Part of the pipe ran through a tunnel, and joints were made at the mouth of one of the tunnels. The joints were all reinforced to 2¼in. thick, and gussets were also put in. The cost of that job, which was located some miles from any car line, was over $30,000, but it saved at least a quarter of a million dollars.

In Fig. 3 is shown an oxy-acetylene cutting machine adapted for cutting out frames for the trucks of motor-cars. Previous to this process, the plates were cut by machine-shop methods, embracing first boring large holes, and then putting them on a planer and a shaper using parting tools. A row of holes is drilled for long curves, the metal broken off, and an air chisel used to trim up. It took three days to get one out; whereas they are now cut out in two hours. They are ⅞in. thick and about 12ft. in length, there being about 45ft. of cutting. Each cut must be set separately, which takes most of the time.

The machine is adapted for a variety of cutting operations of the kind usually handled on a vertical slotting machine or horizontal shaper, but it does the work much faster than a cutting tool. There is a substantial bed for holding heavy steel plates or forgings and an extension at the rear supports the pantagraph motion that guides the cutting torches. The double pantagraph frames are made of steel tubing and all joints provided with ball bearings. A horizontal bar is secured to the pantagraphs at the points opposite their pivots on the vertical supports. The tracing wheel which governs the movements of the torches is attached by a sliding block to any position on this bar according to the pattern or drawing to be followed and the required position of the torches. One or more torches are attached to the bar by similar sliding blocks. The illustration shows the tracing wheel at about the middle of the bar and a torch on each side making duplicate cuts. The tracing wheel is driven by a small electric motor which is provided with a centrifugal governor for regulating the speed at which the torches are moved thereby over the plate or material to be cut.

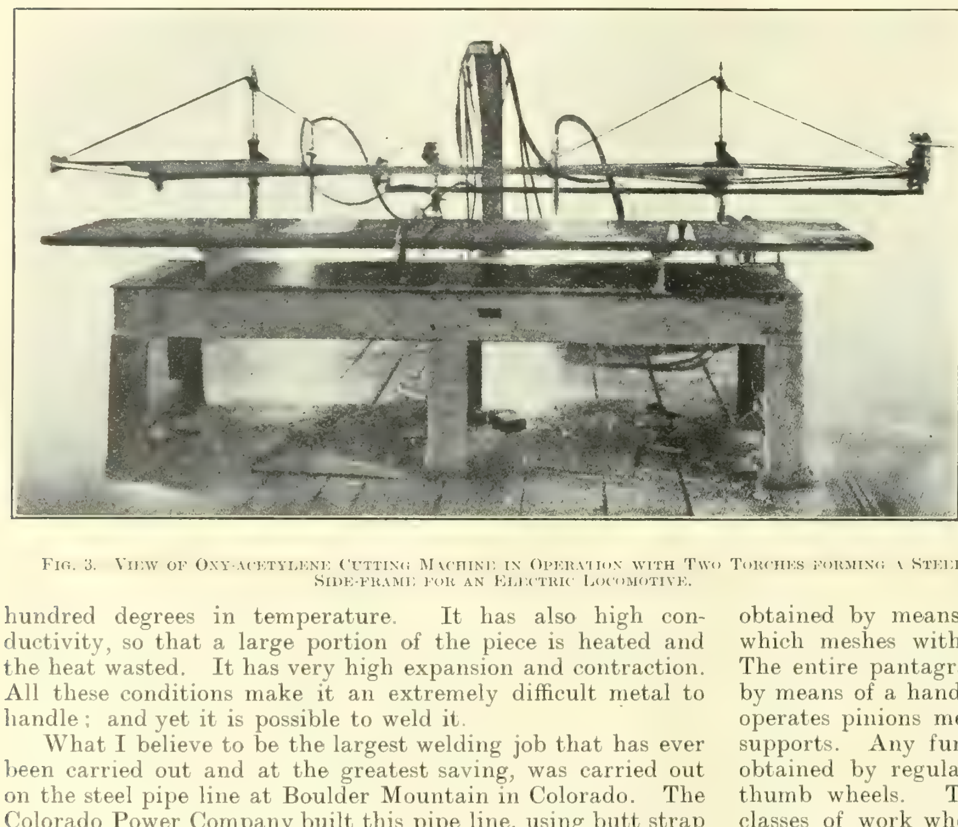


FIG. 3. VIEW OF OXY-ACETYLENE CUTTING MACHINE IN OPERATION WITH TWO TORCHES FORMING A STEEL SIDE-FRAME FOR AN ELECTRIC LOCOMOTIVE.

A full-size drawing of the cut that is to be made is placed under the tracing wheel. The tracing wheel then follows the outline on the drawing and causes the torch or torches to follow a similar path over the work. The most irregular outlines can be easily followed. The speed at which the machine cuts is from 2in. to 12in. per minute, according to the thickness of the work. The torches used are the regular two-hose machine cutting torches manufactured by the Davis-Bournonville Company, vertical adjustment of the torches being obtained by means of a pinion operated by a thumbscrew which meshes with a rack cut in the body of the torch. The entire pantagraph motion can also be adjusted vertically by means of a hand wheel at each end of the machine, which operates pinions meshing with rack teeth cut in the vertical supports. Any further adjustment that is necessary is then obtained by regulating the height of the torches with the thumb wheels. The latter adjustment permits, on certain classes of work where the thickness varies, of adjusting the height of the torch while cutting.

With this machine a cut may be made at any point over a surface 42in. by 84in. in size without shifting the torch on the bar. By shifting the torch or by using two torches, the area over which a cut can be made is increased to 42in. by 168in. Where duplicate work is being done or where two similar cuts are to be made in a single piece, the output of the machine is greatly increased by using two torches simultaneously. An example of this kind is shown in the illustration, Fig. 3, where a steel side frame for an electric locomotive is being cut.

Clearance Limits on British and American Railways.—The clearance limits are much smaller on British than on American lines, although the track gauge, 4ft. 8½in. is the same. The maximum clearance limit on English railways is 13ft. 9in. in height and 9ft. 8in. in width at the platform level. On American railways the maximum clearances are 16½ft. in height and 10½ft. in width.

DRIVING AND REVERSING GEAR FOR ENGINE SHAFTING.

WE illustrate herewith an arrangement of driving and reversing gear for engine or motor shafting, the joint invention of W. Ferguson and D. R. Ferguson, of Sunnyside, Johnstone, N.B. Fig. 1 shows a half sectional plan-view of the gear, Fig. 2 an elevation of same, and Fig. 3 an end view. The gear casing J is slidably mounted on bars M, attached to stationary supporting brackets N. The shafts B and A are mounted in bearings in the gear casing. By sliding the gear casing in one direction the clutch member C, which is attached to the driving shaft B so as to rotate therewith, is thrown into engagement with the clutch member D, secured to the driven shaft, so that motion is transmitted direct to the driven shaft from the driving shaft through the clutch members.

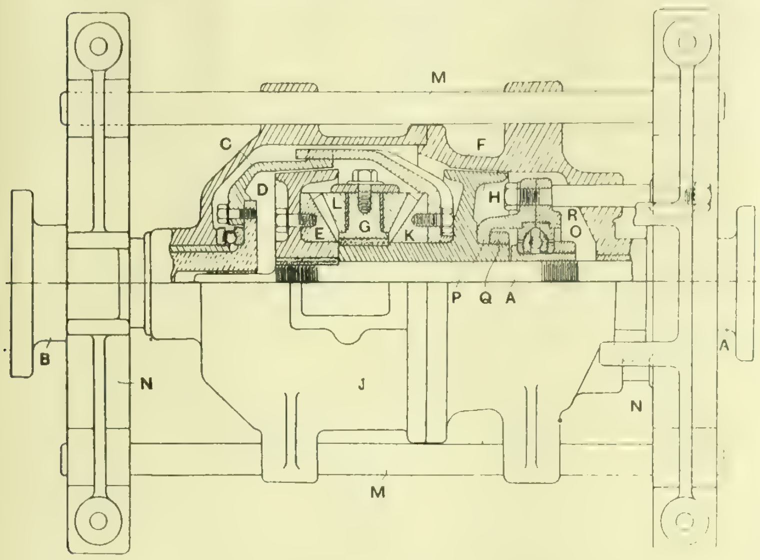


FIG. 1.—DRIVING AND REVERSING GEAR.

By sliding the gear in the opposite direction the clutch member F of the casing is thrown into engagement with the clutch member H, rotatably mounted on the driven shaft, so that the radial arms G, secured to the member H, are held stationary, and the drive is transmitted from the gear wheel K by means of the intermediate bevel wheels L to the gear wheel E, thus reversing the direction of rotation of the driven shaft A. The driven shaft is held against longitudinal movement by means of a double ball-thrust-bearing O. The housing R of the thrust bearing is provided with a ring P, which engages with the clutch member H and nut Q, and thereby secures the member H against longitudinal movement.

The casing is moved by a bent lever T fulcrumed in jaws on one of the stationary brackets, the lever having one end in engagement with a groove in the gear casing, and the other end pivotally connected to a collar U, slidably mounted on a manipulating rod V provided with a hand wheel, and adapted to be screwed into a swivelling nut X, mounted in a jaw S on the other stationary bracket, and, in order to regulate the thrust on the clutches, the lever is loaded by springs arranged between collars secured in any desired position on the rod V by means of set screws, the springs bearing against the slidable collar U. Adjustable stops are provided on the rod V, one on either side of the nut X, to limit the compression of each spring to a definite amount. It will be manifest that by this arrangement the thrust on the clutches can be varied as desired. Thus, the clutches are not dependent on the propeller thrust for keeping them in engagement, and consequently the gear can be used for other than marine work.

A Large Air Compressor.—What is claimed to be the largest compressor so far adopted in connection with the coal-mining industry of Germany has been completed by the Frankfurter Maschinenbau Gesellschaft, of Frankfort-am-Main, for the Werne Collieries of the Georgs Marienhütte Gesellschaft. The machine runs at a speed of 82 revs. per minute, and is capable of compressing 635,580 cub. ft. of air per hour to a pressure of eight atmospheres.

FLAME STANDARDS IN PHOTOMETRY.

IN a paper by E. B. Rosa and E. C. Crittenden contributed to the bulletin of the United States Bureau of Standards, the authors state that although an agreement has been reached regarding the relative values of the units of light in use in different countries, no one primary photometric standard has been generally adopted by the various governments. In Germany preference is given to the Hefner lamp, in England to the pentane lamp, and in France to the Carcel lamp. Each of these serves in its own country both as the primary standard and as a working standard, but for the photometry of electric lamps and generally in accurate photometric work standardised electric incandescent lamps are used in all countries. In America a group of such lamps kept at the Bureau of Standards is considered as a provisional primary standard, serving to maintain the unit until a better primary standard shall have been devised. It is believed that the unit which has been agreed upon can be so maintained with an accuracy considerably above that with which it can be reproduced by reference to any of the so-called reproducible standards at present in use. In other words, the incandescent lamps have really been employed as primary standards, and the flame standards, which logically should play the part of primary standards, have been relegated to a subordinate position.

There is, however, a possibility of an appreciable drift in the value of the unit if there is no photometric standard accurately reproducible from its specifications which is capable of serving as a reliable check upon the electric standards. It has therefore appeared worth while to make a study of the best types of flame lamps to see how closely they would reproduce in the Bureau laboratory the values adopted by international agreement, and also to find whether their reliability as primary standards could be increased by any changes in construction or in operation.

The authors discuss at length the effect of atmospheric conditions on the intensity of flames, and give tables and curves showing the performance of typical lamps. The Carcel lamp is by far the least reliable of the three types, and cannot be considered as a competitor for general acceptance. The Hefner and the pentane lamp as made at present divide honours; the latter is markedly superior as a practical standard, but individual pentane lamps do not agree, and until lamps can be independently made which shall give the same value the type can hardly be said to be reproducible. The Hefner lamp is so simple in construction that reproduction of lamps is relatively easy. Lamps now made show small differences due to slight departures from mean dimensions, but these differences can be made negligible by more careful construction. Great difficulty is experienced, however, in making accurate comparisons of working standards against Hefner lamps because of the very low intensity (0·9 candle) and the red colour of the flame.

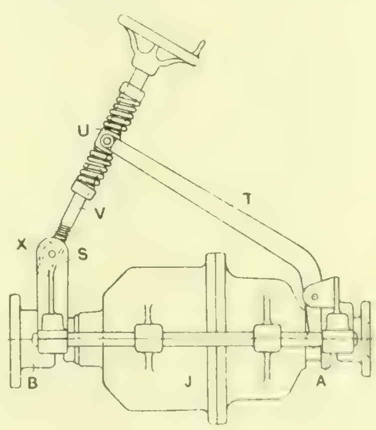


FIG. 2

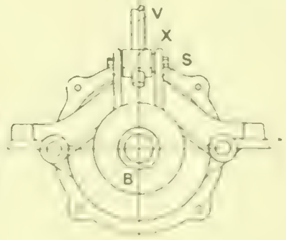


FIG. 3

DRIVING AND REVERSING GEAR.

It is believed to be possible to apply the principle of the present pentane lamp in specially made, accurately specified lamps with interchangeable parts, and thus to obtain a closer agreement between lamps. Then by operating the lamps under definite conditions one should be able to obtain sufficient precision with either the Hefner or the pentane lamp to give a valuable check on the electric standards now in use.

SOME PRESENT-DAY METALLURGICAL PROBLEMS.*

BY D. A. LYON, A.M., METALLURGIST, U. S. BUREAU OF MINES.

ALTHOUGH metallurgy is applied chemistry, it is nevertheless true that metallurgy was the forerunner of chemistry, and is a very ancient art. As is evidenced by the large number of flint instruments which have been discovered from time to time, and in different localities, and which are now to be found in various museums throughout the world, there was a time when metals were entirely unknown, or else had been produced in such small quantities as to prohibit their general use. However, as time went on, men acquired the art of reducing the less refractory metals from their ores. Since copper was one of the first metals to be used, it may be that the copper came from what are known as native deposits, and that later the art of reducing it and other less refractory metals was discovered. Be that as it may, the copper, being soft, had to be hardened, and in ancient times, as to-day, this was done by the addition of a small proportion of iron, arsenic, or tin. At just what period the use of iron became general we do not know, for, due to the rapidity with which it oxidises and likewise due to the fact that oxidation gradually proceeds through the whole mass, an iron instrument left lying alongside of a flint instrument would wholly disappear, and so it may be that iron was used much earlier than we have any record of. However, we are informed that explorers in Egypt and in Assyria discovered specimens of brass and iron which show that the Egyptians were acquainted with the use of iron as much as 4,000 years ago, and possibly even before that time. In the early books of the Old Testament frequent references are made to the use of iron, and so, as before stated, we have every reason to believe that the use of iron was known in very early times. However, for centuries and centuries, metallurgy was more of a craft than an art, and new discoveries were for the most part the result of accident rather than of investigation.

During the Middle Ages alchemy came into vogue, the principal aim of which, we are told, was to discover ways and means for the transmuting of base metals into gold. Although the alchemists were unsuccessful in their attempts, they nevertheless accumulated a large amount of facts on which was based the modern science of chemistry, but it was not until about a century ago that the later science was advanced to anything like its present state of development, and it has only been within that time that metallurgical processes have been carried out on a really scientific basis. As a matter of fact, the advances have been so rapid that the metallurgical profession has come to feel pretty well satisfied with itself. This is due to the fact that a large part of the advancement which has been made has been in the nature of large production at comparatively low costs.

I do not wish to be understood, in this connection, as inferring that present-day metallurgical practice has not been developed along perfectly normal lines; as a matter of fact, it has, but, now that it has reached its present state of development, the metallurgical profession should, and is, turning its attention to perfecting those processes which are in use at the present time, to devising others which will correct existing defects, and to solving some of the many problems which require a solution.

Although we have heard more or less, during recent years, of the possibility of the world's iron ore supplies becoming exhausted, those who have made a special study of the subject inform us that they do not see any immediate prospect of this being the case. While it is true that new ore fields are discovered almost every year, it is equally true that the iron industry is beginning to feel the necessity of turning its attention to the treatment of ores which in the past have not been considered suitable for blastfurnace work, as, for example, those deposits which are found to the western end of the Mesabi Range, where the ore is interbedded with sand. These deposits are very extensive and for a long time they were not considered very valuable. They are now successfully concentrated, and so these deposits have added enormously to the value and extent of the Mesabi reserves. This is also true of many other deposits; namely, that, although too lean to work as raw ores, it is possible by concentration to bring the metallic content of the concentrates up to a point where they correspond to a fairly good ore. Although the metallurgical treatment of such ores requires special care and attention, due to the physical nature of the same, the smelting of them does not present any particularly difficult problems, as do those ores in which the iron is combined, either mechanically or chemically, with some other element or elements, and from which the iron is separated with difficulty, either by mechanical methods or in the metallurgical treatment of the same.

Classification of Iron Ores.—The ores of iron which are used in the production of iron may be arranged according to the following general classification, as given by Turner:[1]

I. Magnetic oxide or magnetite.
 (*a*) Pure magnetites (FeO, Fe_2O_3, Fe_3O_4).
 (*b*) Magnetites in which part of the oxide of iron has been replaced by the oxide of another metal, *e.g.*, chromium (chromite), titanium (ilmenite), or zinc (franklinite).

II. Ferric oxide or hæmatite.
 (*a*) Anhydrous ferric oxide or red hæmatite (Fe_2O_3).
 (*b*) Hydrated ferric oxide, including brown hæmatite, limonite, bog ore, &c.

III. Ferrous carbonate or spathic ores
 (*a*) Pure spathic ores.
 (*b*) Carbonate ores associated with clay (clay iron stones, argillaceous ores) or with bituminous matter (blackband).

As stated, these are the ores that are used in the production of iron. The majority of ores which have heretofore been treated belong to II. (*a*) more or less mixed with those of (*b*). For some time, iron ores of I. (*a*), magnetites, were looked upon with disfavour, even when pure, as being difficult to reduce. The main objection to them, however, has been that they are so often mixed with other impurities, such as silica, titanium, and phosphorus. Silica, of course, if in excess, simply renders the iron too low in iron content to permit of profitable working; if too high in phosphorus, the iron will not make good steel, and if too high in titanium, the general impression has been that in smelting the ores in the blastfurnace sticky slags were produced which interfered with the successful working of the furnace. As to the latter point, the same will be discussed later. On the whole, then, we may say, so far as the subject of ores is concerned, that the problem which immediately concerns the iron metallurgist is the treatment of the complex ores, so to speak—that is, ores containing other metallic elements, and which are considered harmful for either of the following reasons: (1) In the treatment of the ores in the blastfurnace the other elements present in the ore may be reduced with the iron and so impart to it undesirable properties. (2) As in the case of titanium ores, the titanium may render the treatment of the ores difficult, for reasons already explained.

As to the first of these problems, namely, the imparting to the iron of undesirable properties by an alloying element, it is now realised that certain elements which are present in iron ores impart beneficial rather than harmful effects to the fabricated metal. Take, for example, such ores as those of the Moa deposit in Cuba. They carry from 1·5 to 2 per cent. chromium, about half as much nickel, and 8·0 to 12 per cent. alumina. Although the treatment of such an ore is difficult in the blastfurnace, and the steel maker is confronted with certain problems in converting the pig iron into steel, it is up to the metallurgist to conserve these two alloying elements, for alloy steels are now being used more and more, and in case of the Moa deposit it would seem as if there already existed in Nature a combination of elements in the same ore which have proved so beneficial in steel making. As stated by Dr. C. L. Parsons in Bulletin No. 47 of the U. S. Bureau of Mines, "the metallurgy of iron has reached a perfection beyond that of any other metal, and wastes have been eliminated to an extent that serves as some indication of what, perhaps, may be done in other industries when the same intelligent investigation has been applied." If this be true, then it would seem that progress in the metallurgy of iron and steel must be largely along the lines of conservation. However, it must not be inferred from such a statement that conservation has not been taken into account in the industry,

* Abstract of paper presented before the Mining and Metallurgical section of the Franklin Institute.

[1] "The Metallurgy of Iron," by T. Turner, p. 50.

for the saving and use of by products testifies to that. There is, however, still room for conservation, and especially along the lines of the conservation of those elements which are present in ores which have not been treated in the past, as there was no necessity of so doing, with the large supply of pure ores available.

It seems to the writer that one of the greatest problems in conservation, so far as the production of iron is concerned, is the devising of some process whereby the iron which is associated with copper, lead, zinc, &c., in their ores may be saved instead of being thrown over the dump in the form of slag. At present this iron is lost, so far as its use as a metal is concerned. We must, of course, admit that this iron plays its part in the smelting operations—namely, as a basic neutralising agent for the acid materials present in the charge—and the problem, therefore, resolves itself into finding a suitable non-metallic base which will do the same work as the iron does, and a process whereby the iron may be saved and utilised. We must also admit that, even if this iron could be recovered as metallic iron, it might be difficult to find a market for it. However, that part of the difficulty would, no doubt, be overcome if a method could be found for recovering the iron.

If this iron should be alloyed with copper, perhaps all the better, as recent investigations tend to show that copper, when present in iron in proper proportions, inhibits corrosion. The writer is well aware that there are certain investigators who claim that such is not the case—that is, that copper does not prevent corrosion, and that the purer iron is, the less liable it is to be corroded. With due deference to all those who hold this opinion, the writer believes that there is more evidence to warrant the belief that the presence of copper in proper amounts in steel does prevent corrosion, rather than that it does not, or, as some claim, by reason of its being an impurity, promotes it.

The Use of Titaniferous Ores.—At the present time there is more or less prejudice among blastfurnace men against ores containing titanium oxide (TiO_2). Briefly stated, the history of the treatment of titanic ores is as follows: Numerous laboratory investigations have been conducted upon synthetic slags, and small commercial blastfurnaces have been operated upon titanium ores in Norway in 1850, at Norton, England, in 1868, and later by the McIntyre Furnaces in New York. In this connection it is well to note that all successful smelting of titanium iron ores has been done in small furnaces—that is, furnaces having a daily capacity of from 3 to 15 tons of iron. The objections advanced by blastfurnace men of to-day against using titanium ores is that, when smelting ores containing even less than 1 per cent. of titanic acid, cyanonitride collects in the hearth and soon necessitates the closing down of the furnace. In no instance in the operation of the small furnaces was trouble reported from accretions of cyanonitride, and in no instance was it found impossible to make a fluid slag. At Norton, England, both coke and charcoal were employed at different times. As to why the small furnaces were not bothered with accretions of cyanonitride was probably due to the fact that the temperature was too low to form the carbide of titanium, which in combination with the nitrogen of the blast at the tuyeres forms cyanonitride.

The problem, then, of smelting these ores in the modern blastfurnace is seemingly one of duplicating the temperature conditions of the small furnaces that have proved successful. On the other hand, there are metallurgists who state that it is quite easy and perfectly feasible to smelt titanium ores in the modern blastfurnace, and operated in the same manner as when treating simple ores—that is, the charge is made up with such a proportion of ores, fluxes, and fuels as to give a fluid slag—and it is further stated that it is an ill-founded notion that titanic slags are viscous. Due to this diversity of opinion among iron blastfurnace men, the McIntyre Iron Company, which has large titaniferous ore holdings in New York State, has decided to carry on some experiments on a commercial scale at the plant of the Northern Iron Company at Port Henry, New York State. It is hoped, as a result of these experiments, to be able to dispel the uncertainties which now exist as regards the possibilities of being able to successfully smelt titanium ores. For this reason, it is expected that the experiments at Port Henry will be watched with a great deal of interest.

Thus we see that in the iron industry, so far as the use of raw materials is concerned, the problem of the metallurgist is: (1) To so modify existing processes or invent new ones as to enable him to successfully treat, from a commercial standpoint, those ores which have not hitherto been considered as suited to blastfurnace practice. (2) To recover and make use of, as a source of iron, the vast amount of iron that is now thrown over the dump in the slags which are obtained in non-ferrous blastfurnace work. (3) To prevent, if possible, the corrosion of the iron that is produced, either by the addition to it of some element which will inhibit corrosion, or by the production of a pure metal, which, as before stated, is the way some claim to be able to prevent corrosion.

One of the greatest advances which could be made in conservation would be the discovery of some means whereby the corrosion of iron and steel could be prevented. Not only would this mean conservation of iron but of coal. If we calculate the amount of fuel that is used for all purposes, including transportation, installation, &c., we find that it amounts to about three tons of coal for every ton of pig iron produced.

As regards conservation, although the amount of iron and steel which has been produced each year has steadily increased, less ore is now required to produce a ton of steel than was the case, say, in 1890, when nearly four tons of ore were consumed per ton of steel produced, whereas ten years later only 2·7 tons were required, and in 1910 only 2·1 tons. As pointed out by Chamberlain,* though several factors are involved, this decrease in the amount of ore used has been due to the growth of the open-hearth process and the consequent utilisation of scrap.

Fine Ores.—As is well known, it is only within recent years that this problem has arisen in iron blastfurnace work. However, as the richer ores began to grow scarcer, the poorer ones began to be concentrated. Naturally the treatment of these concentrates in the blastfurnace has greatly increased the percentage of fines in the burdening of the furnace, with the result that the furnaces are more difficult to operate than when treating coarser ores. Such being the case, it would seem that some preliminary treatment of these fines, for the purpose of agglomerating them, as well as the flue dust which is produced, would tend to increase the efficiency of the blastfurnace. Inasmuch as considerable progress has already been made along this line—that is, in the way of nodulising and sintering fine ores—it may not be strictly correct to speak of the treatment of fine ores in this manner as a metallurgical problem. Be that as it may, there is, no doubt, considerable room for study along these lines, especially as regards the physical characteristics and the chemical composition of the agglomerated or sintered material, and the effect which the use of these materials has on the efficiency of the furnace.

Problems Connected with the Operation of an Iron Blastfurnace.—Turning now to the operation of the blastfurnace, there are still many problems to be solved in connection with the operation of the same, many of which are mechanical as well as metallurgical. For example, Mr. James Gayley discovered and proved some eight years ago that the use of a dry blast in blastfurnace work greatly increased the efficiency of the furnace. Although, so far as the writer is aware, it is not doubted that the use of the dry blast will greatly increase the efficiency of a furnace, nevertheless its use has not become so general as was predicted, and this, I should say, is due to the fact that the cost of installation of the Gayley system is quite heavy. If this be true—namely, that the use of the dry blast does increase the efficiency of the furnace, but that its adoption has not become general on account of the cost of installing it, or for some other reason—then the problem resolves itself into that of being able to accomplish the same results by some other means.

In addition to the problem of the use of the dry blast, there are many others, which we will not attempt to discuss fully, but which may be stated as follows: (*a*) Production of uniform grades, *i.e.*, less of off grade iron. (*b*) Economy in coke, *i.e.*, by making coke that is put into the furnace do more work, either in the smelting process itself, or by increasing the efficiency of the hot blast stove, or by some other means. Some interesting work has recently been done along this line at a blastfurnace in Belgium. Not only do they dry the blast, but they have also increased its oxygen content from 20·8 per cent. to 23·0 per cent. The oxygen is obtained from liquid air. After separating the oxygen from the more

* G. D. Chamberlain, "Some Developments of the Iron and Steel Industry," "Journal of Industrial and Engineering Chemistry," Vol. V., May, 1913.

volatile gases, the oxygen is finally compressed in holders and used as desired. The enrichment of the blast in this manner is not a new idea. J. E. Johnson obtained patents on a process of this kind in 1908, and has since given the matter more or less thought. (*c*) A further utilisation of the slag.

As is well known, iron blastfurnace slags are now largely used in making Portland cement. However, there is still a large part of it which is put to no better use than ballast for railroads, or for road-making, for which some other material can just as well be used, and so there is still room for a further study of the possible use of iron blastfurnace slags.

The Use of the Electric Furnace for Producing Iron from its Ores.—As is well known, the electric furnace was not evolved in the hopes of competing with the blastfurnace, but of finding a furnace and a process which would be able to produce iron in those localities where blastfurnace practice was not feasible, or, as in Sweden, where the cost of blastfurnace fuel was becoming so great as to cause the existing blastfurnace practice to become prohibitive. The idea of those who first took up the work was to construct a shaft similar to a blastfurnace shaft, and to then substitute electrodes for tuyeres. When this was tried out in practice it was found that the life of the furnace wall in the neighbourhood of the electrodes was short-lived, and no amount of water-cooling served to obviate this difficulty, but rather increased it if anything, due to jackets burning out, &c. As was early observed by Heroult, the proper way to maintain the walls of an electric furnace crucible is to get the electrodes as far removed from the side walls as possible, and in the development of the electric iron reduction furnace in California and in Sweden it was found not only necessary to do this, but also to keep the charge as far as possible from the roof of the crucible, for unless this was done the roof was short-lived, due to the intense local heat which is generated at the point where the electrodes enter the charge. The maintenance of the roof of the crucible was one of the most serious difficulties that had to be overcome, and in overcoming this difficulty the present shape of the roof of the crucible and the manner in which the electrodes are introduced into the crucible were evolved. As a further protection to the roof of the crucible a part of the gases escaping from the top of the shaft were returned to the crucible in order to cool the same, as well as to assist in the reduction of the charge.

Although the Swedish experimenters did not have so much to contend with in this respect, in California the difficulty in securing electrodes that would meet the requirements greatly interfered with the progress of the work. When the latter was begun in California the manufacturers of electrodes in this country had not previously been called upon to furnish electrodes of such large cross-section, namely, about 20in. square and about 72in. in length. Of those first furnished, that part of the electrode projecting into the crucible would either break off completely after it became heated up, or else large chunks would spall off from it, and, as can be readily imagined, these broken pieces gave no end of trouble in operating the furnace.

At the plant of the Noble Electric Steel Company it was finally decided to try graphite electrodes. These worked very satisfactorily in all respects except for the fact that on account of the angle at which it was necessary to insert them in the crucible, due to the manner in which the furnace was constructed, they were subjected to a severe strain which caused them to break at the threaded joints. The electrode problem is, however, no longer a serious matter; 20in. round electrodes are now in use at South Chicago and are giving satisfaction, and at Trollhättan the large carbon electrodes of about the same size as those used at South Chicago meet the requirements.

In an ordinary blastfurnace the weight of the gases produced exceeds the weight of the charge by 30 to 50 per cent., whereas in electric reduction furnace work the bases evolved amount to only about 40 per cent. by weight of the charge. In other words, in the blastfurnace in the production of one ton of iron there is three to four times as much gas given off as there is in the production of one ton of iron in the electric furnace. Moreover, the temperature of the gas as it leaves the tuyeres may be as much as 1,600° C., whereas the highest temperature stated to have been attained at the lower end of the stack in the work at Trollhättan is 985° C. Even if this be granted, and that the temperature of the gas as it enters the stack may have as high a temperature as 1,000° C., as pointed out by Frick, "inasmuch as the weight of the gases produced is only 35 to 45 per cent. of the weight of the charge, the charge would not be heated to more than about 350° C., due to the fact that the specific heat of the gas and that of the charge are about the same." Thus we see that we cannot expect complete reduction in the shaft if we depend solely upon the heat from the gases which are generated in the regular manner. In other words, the shaft acts merely as a preheater, with possibly a small amount of reduction taking place therein, but for the most part reduction takes place in the crucible by means of solid carbon.

Thus we see that an electric furnace may be operated in one of two ways: (1) Reduction of the ore in the crucible by means of solid carbon, with no attempt at reduction in the stack, as is done in California at the present time by the Noble Electric Steel Company. (2) Partial or complete reduction in the stack, this being the idea on which the Swedish furnaces are operated.

As we all know, that which may theoretically be best is not always so in practice. In this instance we are not able to judge by results, as we have not enough accumulated data at our disposal, and so can look at the matter only from a theoretical standpoint. Theoretically,* reduction should take place in the shaft of the electric iron reduction furnace. The problem, therefore, that presents itself is how best to accomplish this; that is, to so operate the furnace as to cause the oxide of iron to be reduced by the time it reaches the electrodes, so that the electric energy shall be called upon to furnish only enough heat to melt the sponge iron, to scorify the gangue materials and fluxes, and to furnish to the products of the furnace the heat necessary for their separation and removal from their furnace.

Among other problems that yet remain to be solved in connection with electric iron furnace work may be mentioned:—

(1) *The Size of the Unit.*—The electric reduction furnaces now in operation vary in size, as regards their horse-power, from 1,500 up to 3,500, while the largest yet designed by A. B. Elektrometall (of Sweden)is 7,500 kw. As can be readily understood, it is quite important that the size of the unit be made as large as possible, and the writer is of the opinion that no one is prepared to say at the present time just what that size will ultimately be.

(2) *Efficiency of the Furnace.*—The efficiency of the furnace will also be increased as time goes on, and probably by improvements along the following lines: (*a*) The utilisation of the waste gases; (*b*) the securing of a high-power factor; (*c*) the correction of induction losses; (*d*) the further study of the single-phase furnace *v.* the 3-phase furnace.

As regards the latter, inasmuch as practically all large power installations are 3-phase, it would seem that the only logical thing to do is to use 3-phase current in electric furnace work, but from data submitted by Catani† it would seem as if the monophase furnace is more efficient than the polyphase furnace.

(3) *The Use of Coke and Crude Oil as Reducing Agents.*—As is well known, of the coke charged into an iron blastfurnace only about two-thirds of the same is used for producing the heat necessary for carrying on the process, while the other one-third is used as a reducing agent. Therefore, if the electric furnace is used for the smelting of iron ores, only enough carbon has to be supplied to unite with the oxygen of the ore; in other words, to reduce it. So far only coke and charcoal have been tried to any extent as reducing agents in the reduction of iron ores in the electric furnace, and of these only charcoal has proven satisfactory. This has been shown by repeated trial runs at Trollhättan, and has been forcibly demonstrated by the fact that the plant at Hardanger, Norway, where coke was used as a reducing agent, after being in operation for about nine months, was forced to close down, due to the fact that nowhere near the same amount of pig iron could be produced per kilowatt-year of electrical energy expended as can be produced when charcoal is used. That this is true is doubtless due to the fact that coke is a

* A theoretical discussion of this subject is given by the author in a paper, "Reduction of Iron Ores in the Electric Furnace," original communication to Eighth International Congress of Applied Chemistry, Vol. XXVI., p. 519.

† "Trans. Amer. Electrochem. Soc.," Vol. XV., p. 168.

much better conductor of electricity than is charcoal, especially after it becomes hot. For this reason, when using coke, the resistance of the charge becomes lowered, and, as the smelting in the electric iron reduction furnace is done by the heat produced by the resistance which the electric current meets with in passing through the charge between the electrodes, more electrical energy is required to produce the same amount of heat. Likewise, as stated by Crawford,* the electrical conductivity of coke "is so good that much of the current passes between the electrodes in the upper part of the furnace. The smelting zone is thereby raised, and the furnace runs hot on top with attendant melting of the arches (of the roof of the crucible) and cold at the bottom. The coke, because of its density and high crushing strain, does not break down like charcoal as the burden descends, hence less surfaces of carbon are exposed to be oxidised by the ore, and there is a less intimate mixture of the two.† Reduction of the ore takes place more slowly, the silicon in the iron is lowered, the consumption per ton increases, and the efficiency of the furnace is reduced."

Inasmuch as either charcoal or coke is the only practical reducing agent we know of at the present time—that is, for use on a large scale—and as it would seem, from what has just been stated, that it is impracticable to use coke, this necessarily limits the electric iron reduction furnace to the use of charcoal. Aside from the possible use of crude oil in connection with electric-furnace work, those interested in the subject have for years been considering the possibility of using it as a reducing agent. So far as we are aware, this has not as yet been successfully done. That the carbon and the hydrogen of the oil will reduce iron oxides is self-evident, but as yet no one seems to have been able to solve the problem as to how to bring the ore and the oil together at the proper temperature. Perhaps ultimately a suitable process may be devised whereby the oil may be used as a reducing agent, and thus broaden the field for the possible application of the electric furnace in the reduction of iron ores, for, from what has been stated above, it is apparent that the electric furnace is limited for such purposes at the present time to those localities where charcoal and electric power are comparatively cheap.

(To be continued.)

CURRENT METERS FOR MEASURING THE FLOW IN LARGE PIPES.

THE accompanying sketches, reproduced from "Engineering News," show current meters adapted to measure the flow in large pipes. Fig. 1 shows the ordinary current meter placed in a 48in. wood-stave pipe to record the daily discharge. To place the meter the valve is closed, the top lid is removed and the meter rod is inserted through the loose disc and the packing box in the lid. The lid is bolted on with the meter in the upper 2ft. section of pipe. The valve is then opened and the rod pushed down until a mark on it shows the position of the meter with respect to the centre of the pipe. The packing box is tightened to hold the rod in place. The meter is of the ordinary type with the wires inside the 1in. brass tube or rod. The wires are connected to batteries and a counter and every tenth revolution of the wheel closes a circuit and is indicated by the counter. This apparatus is suitable for long runs in certain waters. Waters carrying salts in solution are apt to cause deposits on the meter and clog the circuit breaker and movable parts. This is owing to the presence of the batteries which set up an electrolytic action and necessitate frequent cleaning.

A meter constructed similar to the one shown by Fig. 2 is the result of considerable study to avoid this clogging of the meter and to obtain a continuous record of the pipe discharge. This meter is entirely mechanical in its operation. The battery wires are replaced by a small hollow rod about $\frac{3}{16}$in. diam. upon which the meter wheel is hung. The rod extends to a box on the top end of the 1in. tube and is hung with ball bearings at both ends. The box contains a counter driven by the meter wheel and is covered with heavy glass to withstand the internal pressure of the pipe. As in the meter first described, every tenth revolution is recorded.

To determine the relation between the mean velocity of the whole pipe cross section and the centre velocity a number of experiments were conducted at the steel plant of the Colorado Fuel and Iron Company, at Pueblo, Colo., where both meters have been in use for several years. The pipe was

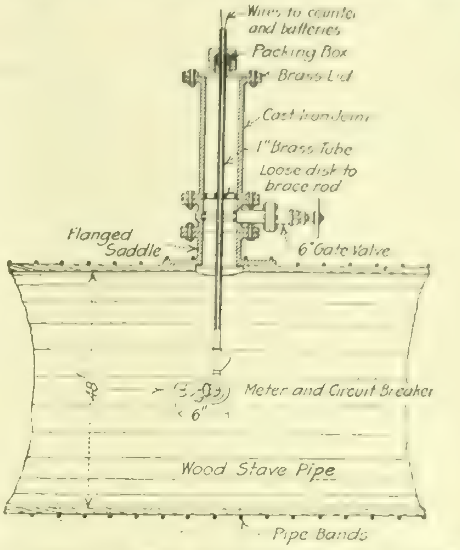


FIG. 1. METHOD OF USING CURRENT METER IN LARGE PIPE.

under approximately 100ft. head, and it was found that the mean velocity of the whole pipe area was very close to 81 per cent. of the centre velocity. There was very little if any difference in velocity at points equally distant from the centre of the pipe.

The meter last described is suitable to record the flow in large pipes. Once placed it requires very little attention unless the water is dirty, in which case the counter acquires a

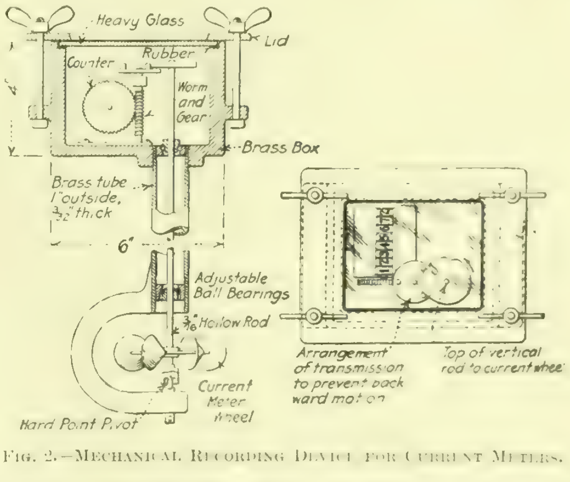


FIG. 2.—MECHANICAL RECORDING DEVICE FOR CURRENT METERS.

thin layer of sediment upon it and requires cleaning occasionally. Owing to the fact that all parts of the mechanism are floating, there is no wear or tendency to collect dirt at the bearings. In clear water it should operate indefinitely and furnish a continuous record of the pipe discharge. The experiments were conducted and the meters designed by A. A. Weiland and the writer under R. M. Hosea, chief engineer of the Colorado Fuel and Iron Company.

The Royal Sanitary Institute.—The 29th Congress of this Institute is to be held at Blackpool from July 4th to 11th, under the presidency of the Right. Hon. the Earl of Derby, P.C., G.C.V.O., C.B. The Congress is arranged in sections dealing with sanitary science and preventive medicine, engineering and architecture, domestic hygiene and hygiene of infancy and childhood, and conferences of representatives of sanitary authorities, port sanitary authorities, medical officers of health, engineers and surveyors to county and sanitary authorities, and veterinary inspectors.

* "Progress of Electric Smelting at Heroult, California," by John Crawford, "Metallurgical and Chemical Engineer," July, 1913, p. 386.

† This intimate mixture is, of course, very necessary where the reduction is almost entirely performed by solid carbon, as is the case in the practice at Heroult, California.—*The Author.*

THE INFLUENCE OF MOLYBDENUM UPON THE CORRODIBILITY OF STEEL.*

BY J. NEWTON FRIEND, D.SC., PH.D., AND C. W. MARSHALL.

In two recent communications Mr. Thomas Swinden† has given the results of a very thorough investigation of the influence of molybdenum upon the physical properties of steel, and it occurred to the present authors that the results might be made still more complete by a careful investigation of the influence of molybdenum upon corrodibility. They desire to express their heartiest thanks to Mr. Swinden for kindly providing them with samples of his steels with which they have been able to carry out the investigation detailed in the present paper. They also desire to express their indebtedness to Messrs. Howell & Co., of Sheffield, who kindly supplied them with carbon steels Nos. 1, 5, and 9, to serve as types. All the steels were tool-turned and cut into cylinders 1·4 centimetre in diameter and 4·0 centimetres in height, and weighed approximately 40 grammes. The surfaces were rendered perfectly smooth with emery. The analyses of the steels were as follows‡:—

Steel No.	Carbon per Cent.	Molybdenum per Cent.	Manganese per Cent.	Silicon per Cent.	Sulphur per Cent.	Phosphorus per Cent.
1	0·14	0·0	0·339	0·157	0·036	trace
2	0·195	1·030	0·218	0·047	0·025	0·016
3	0·246	2·176	0·216	0·064	0·026	0·015
4	0·190	4·110	0·242	0·036	0·020	0·017
5	0·40	0·0	0·357	0·084	0·042	trace
6	0·445	1·054	0·230	0·087	0·026	0·014
7	0·442	2·181	0·270	0·075	0·025	0·015
8	0·487	4·009	0·292	0·038	0·024	0·016
9	1·04	0·0	0·253	0·081	0·049	trace
10	1·215	1·096	0·250	0·124	0·032	0·017
11	1·210	2·109	0·238	0·071	0·023	0·015
12	1·660	4·019	0·230	0·039	0·020	0·016

Five series of experiments were carried out, and the results are, for the sake of easy comparison, grouped together in the accompanying table. In calculating the corrosion factors for each series the loss in weight of steel 1 is taken as 100.

The Corrodibilities of Molybdenum Steels.

Steel No.	Carbon per cent.	Molybdenum per cent.	Tap Water (46 weeks).		Salt Water (42 weeks).		Wet and Dry (14 weeks).		0·05 per cent. Acid (17 weeks).		Mean Corrosion Factor.	0·5 per cent. Acid (10 weeks).	
			Loss in Weight.	Corrosion Factor.	Loss in Weight.	Corrosion Factor.	Loss in Weight.	Corrosion Factor.	Loss in Weight.	Corrosion Factor.		Loss in Weight.	Corrosion Factor.
1*	0·14	0·0	0·6478	100	0·6493	100	0·6267	100	0·5906	100	100·0	2·8781	100
2	0·195	1·030	0·6184	95	0·5252	81	0·6500	104	0·5888	100	95·0	2·7990	97
3	0·246	2·176	0·6598	102	0·6494	100	0·7968	127	0·5314	90	105·0	2·8906	100
4	0·190	4·110	0·6540	101	0·6684	103	0·8234	131	0·5834	99	108·5	2·9872	104
5*	0·40	0·0	0·6470	100	0·7292	112	0·3732	59	0·6182	105	94·0	2·9677	103
6	0·445	1·054	0·6200	96	0·6846	105	0·7090	113	0·5600	97	103·0	2·9868	104
7	0·442	2·181	0·6398	99	0·6102	94	0·9776	156	0·5588	95	111·0	2·9726	103
8	0·487	4·009	0·6840	106	0·6436	99	0·9030	144	0·5040	85	108·5	3·0736	107
9*	1·04	0·0	0·6616	102	0·7660	118	0·2756	44	0·6312	107	93·0	3·1117	108
10	1·215	1·096	0·6628	102	0·7016	108	0·7224	115	0·6044	102	107·0	3·1557	110
11	1·210	2·109	0·6790	105	0·6812	105	0·7900	128	0·6046	102	110·0	3·3294	116
12	1·060	4·019	0·6862	106	0·6272	97	0·9486	151	0·6046	102	114·0	3·1286	109

* The results in these horizontal rows are the mean of two sets of experiments.

1. *Tap Water Tests.*—The samples of steel, resting on discs of paraffin wax, were placed in beakers containing 300 cubic centimetres of tap water, and shielded from light. After 46 weeks the steels were removed, scraped free from rust, and dried in a steam oven. They were then weighed, the loss in weight being taken as a measure of the corrosion.

2. *Salt Water Tests.*—These experiments were carried out in an exactly similar manner to the tap water ones, the liquid corrosive medium being 3 per cent. salt solution.

3. *Sulphuric Acid Tests (0·05 per cent.).* In these experiments the corroding liquid consisted of a solution of 0·5 gramme of sulphuric acid in 1,000 grammes of water. The liquid was frequently renewed.

4. *Sulphuric Acid Tests (0·5 per cent.).* In these experiments the corroding liquid consisted of a solution of 5·0 grammes of sulphuric acid in 1,000 grammes of water. The liquid was frequently renewed.

5. *Alternate Wet and Dry Tests.*—In these experiments the steels were laid upon a perforated disc of paraffin wax suspended in a metal bath, which was alternately filled with water and emptied, as described in a previous paper.* The steels were thus exposed to alternate wet and dry action.

Discussion of the Results. An examination of the table makes clear the following points:—

1. Molybdenum up to 4 per cent. does not appear to exert any marked influence upon the corrodibility of steel, when exposed to tap water, salt solution, and dilute sulphuric acid.

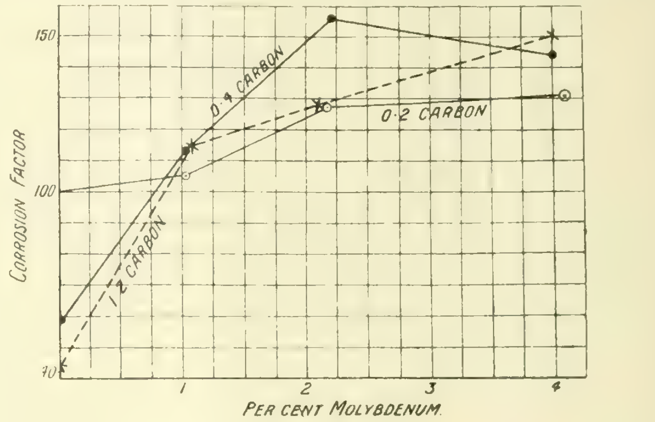


FIG. 1.

2. The results of exposure to 0·5 per cent. sulphuric acid are almost identical with the mean corrosion factors obtained by the exposure of the steels to the other four corroding agencies listed in the table. This is interesting, because it so frequently happens† that the solubility of steels in the stronger solutions of sulphuric acid gives entirely unique results, which are quite untrustworthy guides as to the behaviour of the metal towards neutral corroding agencies

3. The greatest variation in the corrosive factors is exhibited in the wet and dry tests, the resistance of the steels greatly increasing with the percentage of carbon (*see* steels 1, 5, and 9).‡ The molybdenum, on the other hand, tends to increase the corrosion very markedly. The points are clearly brought out by the curves in Fig. 1. It is difficult to say what conclusions we are to arrive at from this, but if, as the writers believe, the wet and dry tests correspond most closely to the conditions under which steel ordinarily corrodes in practice, it is clear that, from the corrosion point of view, molybdenum is an undesirable constituent of steel if present to a greater extent than 1 per cent.

These conflicting results emphasize still more forcibly the "necessity of determining the corrosion of iron and steel under conditions closely similar to those which the metal will be subjected to in practice."§

* Paper read before the Iron and Steel Institute, May, 1914.
† "Carnegie Scholarship Memoirs," 1911, Vol. III., p. 66; 1913, Vol. V. p. 100.
‡ With the exception of the carbon steels Nos. 1, 5, and 9, the analyses are those given by Mr. Swinden, *loc. cit.*

* "Journal of the Iron and Steel Institute," 1912, No. I. p. 253.
† "Journal of the Iron and Steel Institute," 1913, No. I. p. 397.
‡ Contrast the results of Chappell, *ibid* 1912, No. I. p. 270.
§ "Journal of the Iron and Steel Institute," 1912, No. I. p. 258.

ANNEALED CASTINGS FOR TEXTILE MACHINE SPINDLES.*

BY ROBERT BUCHANAN.

CERTAIN difficulties which some of my friends have had recently with these castings provide the reason which urges me to put before you some matters for your consideration. Some years ago I discussed the principal points with one of our members. He did not altogether agree with my conclusions, but whether he does now agree with me or not is not of the first importance to either of us. What is of importance is to find a solution for a trouble of which I shall speak later. I am here giving my own ideas and experience, and I shall welcome criticism which will extend our knowledge of this subject and thus help to obviate a difficulty often met with by makers and users of these castings. In view of the enormous textile machine industry, principally centred in Lancashire and Yorkshire, but with outlying points in Ireland and Scotland, no apology for introducing the subject is necessary.

The cast iron used in spindle making is always annealed, and is known under the generic name of "black iron." That cast from part hematite, or from irons with about 1 per cent. phosphorus, exhibits a fine velvety fracture after proper annealing. In such a case there is practically no combined carbon present, all the carbon being in the form of graphite and annealing carbon. It is this complete separation of the carbon which principally gives the iron its velvety appearance when broken. One firm which produces these castings states that they may be machined at 600ft. speed per minute. In a good sample of this kind I have cut off a small paring with an ordinary pocket knife. I am aware that some makers use annealed castings made from their ordinary mixtures. These are not so dead-soft as the true "black" iron, and do not machine so easily and quickly, but they have undoubtedly more wear in them; that is, they have a longer working life. Naturally, firms who are spindle-makers only are more concerned about the speed of production than about the after life of the spindle. I have, however, heard complaint made that the spindles can be too soft from the users' point of view. An iron suited for these castings and combining the best average qualities for rapid production and long life in work will approximate to the following analysis:—

	Per cent.
Silicon	not exceeding 2
Phosphorus	not exceeding 1
Manganese	0·85 to 1
Sulphur	0·80
Total carbon	as high as possible.

As I have already said, the annealing is for the purpose of changing into the form of "annealing" carbon all the combined carbon present in the casting as originally cast. One could probably do that without annealing, by the use of high-silicon iron, say, 3·25 to 3·5 per cent., but such an iron would be deficient in total carbon. Partly from this cause, and partly from the fact that such a percentage of silicon would itself conduce to a harder product, the resulting iron, even when annealed, would not be so soft as one wherein the silicon was at the normal amount of 2 per cent. In short, the silicon should be present only to such an amount as will make certain the castings will be grey when cast.

The percentages of phosphorus, manganese, and sulphur given above are practically neutral, but with a tendency to increase the wear of the metal. Of the moulding of the castings little need be said. They present no difficulty unless it be in the case of "long collars," and even in this case it is long cores of small diameter which present the difficulty. It will be in the recollection of the members that when we visited the works of Messrs. Tweedale & Smalley, Ltd., Castleton, near Manchester, some few years ago we there saw in use a core-making machine successfully producing these cores. I was particularly interested in this machine, as I had recently failed to have similar cores made successfully, in ordinary core boxes. We also tried making these cores by means of a "Wadsworth" core-making machine. The cores were made fairly well, but as our conditions did not allow us to cast the boxes on end, the cores lifted in the middle owing to there being no core rod in them. In the finished spindle there must be absolute balance, and for this they are carefully tested before being passed, so a thick and thin side on any casting at once condemns it. I have been informed that there are always plenty of orders for anyone who can tackle "long collars" successfully.

The annealing cans into which the castings are packed, are best cast of white hematite or other metal with a high melting point. In the "Black Country" these have also usually a large proportion of waste malleable castings melted along with the hematite. These cans retain their shape well, considering the service they do, and are still white when broken up at the end of their service. Sometimes a round can may be beaten oval before it will break. When being made they are cast in open-top moulds made in sharp sand.

When castings are long the can is heightened by means of a ring or bottomless can of similar material being placed on top of a can having a bottom. In some places the cans have no bottom cast on, but use loose bottom plates which rest on a ring cast inside the can. By this means any height of can may be built up, and by putting the top can with an internal ring at top, one of the loose plates can be used as a cover, and so luted on with fireclay. The annealing cans are of varied shape; some firms have them round, others rectangular, and in one case I have seen they are oval.

When the cans are large, snugs or swivels are used by which the cans are withdrawn from the annealing oven by means of "tongs" 10ft. or 12ft. long, mounted on a pair of wheels. The tongs swivel on the axle on which the wheels are placed. When annealing ovens are continuous in action, these tongs are necessary for the withdrawal of the cans. The tongs are run up to the oven, the ends put under the snugs or swivels on each side of the can, and so the can is withdrawn. On oval cans there are two swivels on each side, each being similar to those on a moulding box. This allows the can to be balanced during withdrawal. The cans sometimes have lids which are luted on with fireclay, in other cases they are left open-topped. In the case of non-continuous annealing ovens, these are entered when they have cooled down sufficiently, and the cans and their contents carried out by hand.

Various packing materials are in use. Small gas coke which has passed through a quarter-inch riddle is one. Others use cast-iron borings. In one case I found a mixture of cast-iron turnings and red hematite ore was being used. This was a wrong material. It was thought that because red hematite ore was being used when annealing malleable-iron castings, therefore it was a suitable material in which to anneal these castings; but the fact was overlooked that with the castings now being considered retention and not lessening of the carbon was desired. The sole object in packing the castings is that they may not twist or warp during the anneal. Long castings should be placed vertically in the cans. When used as a packing material, small coke "sags" under heat more than do cast-iron turnings or borings. This induces warping of the castings, especially if the oven has been over-heated.

Annealing ovens may be divided into non-continuous and continuous. In the non-continuous oven the cans are allowed to cool down in the oven. This is the ideal way to get dead-soft castings. These ovens may be, and usually are, in a battery of five or six, connected by individual flues to one central chimney stack. The ovens are known as "25-can ovens," or "40-can ovens," according to capacity. The fire-grates are on each side of the oven, are sunk about 4in. below the floor level, are 12in. wide, and extend the whole length of the oven. That is, the fire-grate is about 9ft. long by 1ft. wide. Before the cans are put into the oven lump coal is piled about 4ft. high over each fire-grate. This is all the fuel used; there is no subsequent firing. The fire doors are used only to start the fire and to remove clinker, &c., after the oven has cooled down. When the two walls of coal have been built the cans are placed in position. As this is done by hand, the highest point of the roof inside does not exceed 6ft. 6in. to 7ft.

The cans, which are ready packed with castings embedded in coke dust of cast-iron borings, are placed along the sides next the coal, and at the end furthest from the entrance. This is continued until the oven holds as many cans as it will contain. The opening is now bricked up loosely, and daubed with loam or mud. About 9in. above the floor level a brick

* Paper read before the annual convention of the British Foundrymen's Association, Leicester, May, 1914.

is left sticking out so that it may be readily removed when the "soaking" begins. In about 12 hours from being lit up, the coal on each side of the oven is a glowing mass, and all visible smoke has gone. The interior of the oven is now a bright red, but the heat has not yet penetrated to the centre of the bottom cans. The "soak" is accomplished by withdrawing the brick which was left sticking out when the opening was built up, and closing the damper in the flue which leads to the central chimney stack. After "soaking" for 10 or 12 hours, the brick is replaced and the whole oven allowed to cool down. In 48 hours or so after the coal is lit the bricks closing the entrance to the oven are taken down, and the cans are withdrawn and emptied.

There is no definite type of continuous annealing oven. They have this in common that only one row of cans is annealed at one time. The fire is at one side only in most cases, and the flames enter the oven through holes or ports in the wall, and leave the oven by similar ports in the opposite wall. Sometimes the flames are led to the flues through holes in the floor of the oven. The length of time the cans are kept in the oven depends upon the size of can used. When the cans are considered to have been thoroughly heated through, the brick-lined door (or doors) is opened, the cans withdrawn, and others placed in the oven.

It is obvious that cans which are allowed to cool in the open do not get so good a chance of producing soft castings as do those which cool within the oven. Neither do they have the important advantage of the thorough "soak" possible in the non-continuous type of oven.

The object of the annealing is obviously to change the combined carbon into the form of annealing carbon, and thereby make the casting still softer than it was originally. It will be admitted, I think, that with a normal amount of silicon, say, 2 to 2½ per cent., there is certain to be an appreciable amount of combined carbon in the castings. The smaller or thinner the castings are so will the amount of combined carbon be increased. The annealing is required to decompose this compound of iron and carbon into iron plus free carbon. That is what takes place when the annealing is perfect.

I now come to a consideration of the matter which has caused this paper to be written and submitted to you. Occasionally it is found that during the course of the annealing the castings have acquired an exceedingly hard, white skin which no tool will touch. The interior of the casting is quite soft, but that is of no use if one cannot get through the hard outer skin. That this is not a small matter is evidenced by the fact that I have seen a 30-ton heap of such castings, none of which could be machined. It is also within my knowledge that this hard skin causes serious loss to several producers of these castings at the present time.

As the outside of the castings could be readily filed before the anneal, and could not possibly be filed after the anneal, it was obvious that the hard skin was acquired during the annealing. It has been suggested to me that this hard skin may be due to oxidation, but there cannot be oxidation of a casting perfectly covered with coke. If the coke sags sufficiently to expose the casting to the flame and gases of the oven, the casting becomes oxidised, but the oxide is red. Neither am I aware of any oxide of a metal which is harder than the metal itself. Neither have I met as yet a white oxide of iron.

A consideration of the whole circumstances brought me to the conclusion that the hard skin was brought into being by the agency of sulphur present in the packing material. This was confirmed by analysis of the small gas coke which was being used for this purpose. The sulphur contents approximated 2½ per cent. This sulphur was undoubtedly in greater quantity than what was originally present in the coke. The increased sulphur was obtained from the flames which fill the oven. It is well known that iron and steel take up sulphur from sulphurous flames and gases. Thus, whether cans are covered with lids or not, sulphur can be passed into the charge inside. The fact that the cans, white iron originally, remain white after many times annealing, shows that a cause is constantly operative to keep them white. It has not come within my observation whether cans which are originally grey iron become white under annealing conditions.

The deduction that sulphur was the cause of the trouble was proved to be correct by the hard skin not appearing when the packing material was changed oftener. It did not get the opportunity to become surcharged with sulphur. An additional precaution was to cover the top of the can with lime. This was used as an absorbent for sulphur, and no doubt helped to take it up and hold it. The lime, however, was rather an irritant to the men when packing and emptying cans. My own experience is greater with coke packings than with cast-iron borings, but from what I have seen of both kinds, the white, hard, unmachineable skin is thicker with coke packing than it is with cast-iron borings.

The conclusions to be drawn are these: (1) Non-continuous annealing ovens produce softer castings than do continuous ovens. (2) The hard skin which occasionally appears on the castings is due to the influence of excessive sulphur contained in the packing material. Also the sulphur originally present in the packing material is augmented during each subsequent heating, and this additional sulphur comes from the fuel used in firing. (3) Coke dust contains from five to ten times the quantity of sulphur contained in cast-iron borings, and thus gets more quickly to the point at which it parts with sulphur to the castings. (4) If coke dust is used, an addition of lime retards the effect of the sulphur. (5) Coke dust "sags" during annealing more than cast-iron borings do, and with it warped castings are more common, especially if there has been overheating of the oven. (6) The packings should be changed often so that the sulphur may not reach the saturation point where it passes the sulphur into the castings.

THE PRESENT STATE OF THE ELECTRICAL INDUSTRIES IN JAPAN.*

BY PROF. SHUNKICHI KIMURA, PH.D.

THE protective policy and the encouragement of home industries now in vogue in Japan for averting the disastrous trend of financial conditions as well as for improving the national standard of wealth, have created a disturbance in the system of industrial commerce which has developed during the last 30 years. But at the same time a new and interesting field has been opened up for those who will accommodate themselves to the changed conditions or for those who keep a smart look-out for new opportunities. On our side we ought not to aim at independence from the industries of the West, which might lead to our isolation; on the contrary, the relations between the industries in this country and those in the West should be made much closer than ever. Nor should our object be the exclusion of foreign arts and inventions, which will certainly lead us to sterility; on the contrary, importation and exportation must be mutual and must be encouraged to an ever-increasing extent. Home industry in Japan is progressing, no doubt, but much more slowly than in Europe or America, and in the case of electrical industries Japan is from 10 to 15 years behind other countries in the West.

In the domain of electrical industries, water-power plants throughout the country are numerous and widely distributed; those mountain streams with shallow basins, long regarded as the cause of all kinds of troubles, are now being rapidly turned into sources of electric power. According to the most reliable report, those water-power plants alone which can be most easily and economically turned to electric power amount in the aggregate to about 10,000,000 h.p.; of this only 300,000 have already been utilised for the public, while one-half of it is in actual operation, and that mostly for lighting and power in cities and towns. Such sources of power will mean a great deal in future, when they are economically employed on the spot, not with the object of selling the electricity, but in manufacturing commercial products with the energy, which may be used as transmissible motive power or can easily be transformed into intense heat or a powerful electrolytic agent.

Changes in the order of things are perplexing, not only to the foreign merchants and native contractors, but also to home industries themselves. To return to electrical industries, ordinary types of motors, generators, and transformers are now made here of creditable quality, but iron and steel of special descriptions are imported every year to a great amount. Patent rights and manufacturing processes may be acquired from abroad, but without the help of trained foreign engineers, at least during the trial stage, it will be difficult

* From the Journal of the Royal Society of Arts.

to turn out articles of high-class quality. Investigations are being made, no doubt, to a certain extent, but the progress is slow and the results doubtful, as expenses for research work are generally too heavy to be borne; in the meantime, foreign countries will make great progress, and even when the researches lead to success the market here is very small and the means for international business extremely limited. Apparently there is a great boom in electrical industries in Japan, yet, if we deduct the imported articles, only a little will remain as the genuine product of home industry. One hears from contractors that all kinds of machines, both mechanical and electrical, are still imported through their hands, without any change, for places where reliable machines are in demand. These contractors are generally large firms, having long experience and trained hands. The so-called importers, whose business is conducted by foreigners with low-grade native employés, and without respectable Japanese associates, seem to have felt the effects of the change.

The study of all systems, both those which are obsolete and those which are still flourishing, must enrich one's experience and judgment, and enable one to meet the changed conditions. Joint capital, joint management, exploitation of patents and manufacturing processes—these are, generally speaking, worthy of recommendation. Of the present system of industry, as regards either sale or management on a scale fit for cheap production and a wide market, Japanese men of business have as yet had only short experience. Those industries which are now flourishing do not belong to the class of pioneer industries, and the channels of business have been prepared by the so-called importers. It will be clear that the co-operation of foreigners trained in international business is desirable, while for the manufacture of articles, complicated as regards process, delicate in fixing, or precise in measurement, the co-operation of trained foreign hands will be imperative. But on the side of management, dealing with customers, understanding public taste, and the proper ways of speaking and writing, or in selecting the right person to communicate with—in short, in all that cannot be reached by reasoning and calculations alone—the co-operation of Japanese managers will be desirable. Further, the protective policy of the Government and its general encouragement of home industries will be met by joint capitalisation. The days of monopolising interests are now gone for ever, and the day has come for mutual interest with joint responsibility, the rights of both parties being justly considered and clearly defined. There are already instances of such joint capital and joint management, some of which are apparently failing, while others are likely to succeed. If we look closely into these cases, however, it will not be difficult to find out ample reasons for these failures and successes. Both kinds are equally full of lessons for those who would avail themselves of the opportunities now offered by the changed conditions. Such a change is ever to be welcomed, and here lies a chance for new men in the field.

To me it seems that foreign firms and inventors are too neglectful of securing their patent rights in Japan. All the details of their inventions, so far as they are expounded in the technical papers in their own lands, are of course open to public scrutiny here, and the so-called inventors here may resort to these papers and utilise them for their own benefit. In granting patent rights in this country, officials do not search through foreign patent records; it is advisable, therefore, that the real inventors or the lawful possessors of patent rights should pay more attention to this matter. The best thing to be done would be to secure their patent rights here, and to look at once for their exploitation, either in the form of co-operative working, or of selling the right, or else on the basis of royalties. It is to be remarked, however, that the market here, being national and not international, is, of course, too small for large industries; and the most profitable inventions will be those dealing with the commonest kinds of articles, widely used in industry or by the public, or else such as will replace others which have already created a good market in this country.

In the exploitation of inventions and manufacturing processes there is one thing which might with benefit be resorted to. This is the publication in industrial or trade journals, in the Japanese language, of the general nature of the invention, or the manufacturing facilities, of the properties of articles made, of places in which they may be most profitably employed, and so forth, accompanied with cuts or illustrations, and, when necessary, with the result of scientific testings, and with anything which will instruct people and induce them to make further enquiry. A few lines of advertisement in daily papers offering for sale the patent rights are of course useless, since their nature can only be understood by a few specialists, but not by the men who might take real interest in the transaction.

The following brief survey of the present state of electrical industries in Japan may be of some interest. The data have been collected within the last six months in the factories throughout the country and under my own personal observation. Motors, generators, and transformers are made here in large quantities, to meet a very great demand which increases every year. As to the size, generators have been made up to 6,000 kw., giving very good results under test. There are two large factories with long experience, one in some connection with the General Electric Company of the United States of America, the other as a part of a dockyard. Besides there is a large factory adjoining and in possession of a copper mine, which promises to have a splendid future. Smaller factories which turn out smaller articles are many in number, and compete keenly with each other. All special iron and steel parts are imported, and these factories have always to keep them in stock, thereby causing unnecessary loss and inconvenience. Special types of machines, and those directly coupled with water and steam turbines, have been supplied by the importers and contractors; but even these are now being made in Japan to a small extent.

Carbon filament lamps are made here in a satisfactory way, though some difficulty is experienced in making them for 220 volts, and the filaments of superior qualities are all imported. Tungsten lamps of ordinary size are also made here in many places, both drawn and squirted wires being imported. Large factories in Kawasaki and Osaka are turning out tens of thousands of lamps every day, yet hardly enough to meet the public demand.

Porcelain insulators of good quality are made here to a large amount, leaving no room for importation, as suitable raw materials are plentiful in Kiushiu and other places, but the manufacture of straight and uniform tubes seems to be limited to the length of about 30 cm. Most of the large factories have reliable sets of apparatus for testing insulators, but these latter, when furnished with transmission wires, sometimes give way with the normal working voltage. Among solid insulating materials, other than porcelain, ebonite is the only sort which can be made in a good quality. No substitutes for ebonite nor any insulators to meet special circumstances are yet forthcoming, although such forms as lamp sockets or ball insulators for trolley lines are made to a great extent. Mica is largely found in Corea and Manchu, though the quality is not high grade. It appears exposed as rock or rather as an assemblage of small rocks, and there is a prospect of finding the mineral of good quality in deeper places in the mines. It is still good enough for making some sort of micanite; but there was no factory for it till very recently, when some attempts in this direction have been made with good prospects of success. Superior kinds of mica are imported through London firms from India, and in most of the electric workshops it is used even where smaller pieces of inferior quality are good enough for the purpose. Engineers do not seem yet fully to understand the values of the different sorts of micanite. Indeed, it is now a general feature here, that in spite of the keen competition under which they are struggling they do not look for the new materials which they may use with much profit in place of old ones, and in order to avoid the unnecessary expense in the production of their articles. Very recently a patent right for bakerite has been acquired, and the manufacture will begin after one year. India-rubber insulating tapes are made in many places, usually on a small scale and in a very primitive way. Insulating compounds and varnishes are made only to a small extent; and none with special features are yet touched upon. Transformer oils are made at oil refineries, but it

is not known whether they meet the strict requirements of electrical engineers. All other oils for making varnishes and compounds are imported, and they secure good prices.

Ammeters, voltmeters, and kilowatt-hour meters are largely imported. Ammeters and voltmeters for A.C. and D.C. are also made here on a fair business scale, and supplied for use with small motors, but they serve for indicating rather than for measuring, and the consumers of electric power in general are indifferent. I have seen such meters in process of calibration by an ordinary workman with no proper education for such work, who was giving an allowance of 20 per cent. either way, and calibrating with the fluctuating city supply as the electric source. There are some factories, however, where they make switchboard instruments, accurate to within 3 or 4 per cent., supplied with the generators made by themselves, but these cost much more than imported ones made by well-known specialist firms in America and Europe. There is no manufacturer of instruments of precision fit for scientific use. For hot-wire instruments there is difficulty in obtaining proper wires. In some factories resistance boxes are made, but with materials having high temperature coefficients.

The employment of physicists in factories began only a few years ago, and there are still places where men with no proper education hold the place of chief engineer. There is no place such as the National Physical Laboratory, or the Bureau of Standards, with a staff of the highest scientific reputation and with adequate modern equipment for research work. The development of the potentiometer must help them a great deal, but I have not seen at any commercial industrial workshop a really good potentiometer from well-known makers, and preserved in perfect condition, nor have I seen a battery of secondary cells for the electric source in calibration or testing of D.C. instruments, or in driving a motor-generator for A.C. instruments. Such special instruments as the oscillograph are still considered a luxurious equipment in places where they are much needed; but ohmmeters and such like are used to a great extent. Those meters, which serve in selling and buying electricity, must now pass the examination of the Teishinsho (Department of Communication). Among these meters, tariff meters are imported to a large amount, but competition being keen, and under the public idea that electric apparatus has no fixed price, they are sold at half the catalogue price, and in addition one quarter of the selling price is paid for the fee of examination. The number of these meters examined at the Teishinsho last year reached 38,000, and the figure increases every year at a rapid rate.

None of the alloys used as the materials for electric resistances, except a small amount of German silver, are made here, and the manufacture of such alloys is in a very primitive stage. Consequently all heating elements must be imported.

Rubber works are in a prosperous condition, but not sufficiently so to stop the importation entirely. Good rubber is, of course, imported from South America through London and New York firms, inferior quality rubber comes from the Straits Settlements, while the experimental cultivation of the tree in Formosa is likely to end in disappointment.

Copper wires of all descriptions, from power cables down to silk-covered wires and rubber cords, are made here almost to the entire exclusion of imported articles, and all these factories are apparently in a prosperous condition, though competition is very keen in this as in other industries. Enamelled wires are made in some of the factories, but the demand is still small and not yet established. Owners of copper mines and refineries have begun to make wires themselves, and the factories with no mines of their own are feeling a handicap in this respect. Copper wires of small diameters are drawn up to No. 50 S.W.G.; 15 years ago I had to wait six months to import a piece of No. 42.

Dry cells are made in many places on a small scale, but the demand is increasing every year. Most of the factories do not possess the proper apparatus for testing their products, the general public accepting them untested, while in supplying Governmental customers rigorous specifications are observed. Dry cells fit for storing, made of the type in which some liquid is poured in at the time they are used, are in demand by the Army, the Navy, and in the telegraph and telephone departments. Secondary cells of lead type are now made in two or three places, but the greater part of the demand, which is increasing every year, is supplied by importers. Those who are going to install them naturally pay attention to the life of the cells, and therefore look for the products of well-established foreign factories, native factories being still too young to ensure good records for their products. Governmental customers use the native products, because they are instructed to do so, and they have no personal interest in the question.

Electric carbons for dry cells and for arc lamps, and also those carbons which do not require special processes, are made in many places, though on a small scale. Thick carbon rods for searchlights and carbon granules for telephone work are not yet made here in proper quality; carbon brushes, though made, are much inferior to imported ones.

Public telephones and telegraphs are Government monopolies, and the apparatus, being fixed in form, are old in type, except in few instances where new inventions are employed by way of trials. Most of these public telephone and telegraph apparatus have been supplied by two firms, one purely Japanese and the other in close connection with the West, and the apparatus were subjected to severe trials according to the policy of the Government. As to the telephone, any new apparatus may be used after Government inspection, but the public is not very particular about it. Automatic exchanges are not yet installed for public service, but semi-automatic ones will some day take the place of hard-worked female operators.

Fittings for lighting used in Japanese houses are developing to meet the taste of the people; but those for buildings of foreign style, for offices and dwelling-houses, which are increasing very rapidly, are imported articles. No electric irons are made here, nor any electric heaters or cooking utensils, while electric fans are only manufactured to a very limited extent. Suppliers of electricity are now competing fiercely with one another, but for current for lighting purposes only. When this contest comes to an end, and that will be very soon, the manufacture of all kinds of apparatus for domestic purposes will rise quickly to a state of prosperity.

Physical Society of London.—The following papers are down for reading at the meeting of this society, to be held to-day (Friday), the 26th inst.: (1) "On Atmospheric Refraction and its Bearing on the Transmission of Electromagnetic Waves round the Earth's Surface," by Prof. J. A. Fleming, M.A., D.Sc., F.R.S.; (2) "Atmospheric Electricity Observations made at Kew Observatory," by Gordon Dobson, B.A.; (3) "Thermal and Electrical Conductivities of some of the Rarer Metals and Alloys," by T. Barratt, A.R.C.Sc., B.Sc.; (4) "On the Measurement of the Temperature Coefficient of Young's Modulus for Metallic Wires with Special Application to Nickel," by Prof. E. P. Harrison: (5) "Some Investigations on the Arc as a Generator of High-frequency Oscillations," by F. Mercer, B.Eng.

Calorific Power Standard for Gas.—At the annual meeting of the Institution of Gas Engineers, held last week in Liverpool, Mr. Edward Allen, M.Inst.C.E., in his presidential address, said that a review of the past year should include a reference to recent legislation, by which it was now certain that the industry would be relieved from the obligation in regard to illuminating power. The adoption of a calorific power standard would ensure the supply of gas best suited to the requirements of the public, and which could be manufactured at a minimum cost. This wise course would make the way easier to establish a uniform quality of gas for the whole country, and lead to the manufacture of standardised gas appliances of maximum efficiencies. It also enlarged the field of coal supplies, with consequently a cheaper market, and rendered it possible for undertakings to have a greater selection of carbonising systems with a view to reduced cost of working. The flat-flame consumer would, of course, receive less consideration than in former years; but, with very few exceptions, he could adopt incandescent burners with enormous advantage to himself. The application of the policy to the gas industry of "the greater good for the greatest number" was not only justified, but demanded in the interests of the public.

INDUSTRIAL AND TRADE NOTES.

Personal.—At the annual meeting of the Shipbuilding Employers' Federation, held in Edinburgh on the 18th inst., Mr. J. W. Hamilton, of Messrs. William Hamilton & Co., Port Glasgow, was elected president in succession to Mr. Herbert Powell, of Messrs. Hawthorn, Leslie, & Co., Newcastle on Tyne.

An Acetylene Order.—The "London Gazette" dated the 19th inst. contained an Order in Council extending the Explosives Act to acetylene when liquid or subject to a certain degree of compression, or when in admixture with air or oxygen, and prohibiting, in the interests of public safety, the manufacture, keeping, importation, conveyance, or sale of such acetylene. Acetylene not possessing the explosive properties set forth in the Order, or which is in admixture with air in a burner or proper acetylene production apparatus, is exempted.

Geared Turbine Steamer.—The Cairn Line, of Newcastle, have ordered from Messrs. Wm. Doxford & Sons, Sunderland, a cargo steamer of 5,500 tons. She is to be fitted with geared turbines, like the "Cairnross," which was the first purely cargo steamer to be especially equipped with such machinery. She is, however, to receive the turbines taken from the steamer "Vespasian," which, it will be remembered, was used by Sir Charles Parsons to prove the applicability of geared turbines to slow speed cargo boats. The new vessel will be the second purely cargo boat to have this type of machinery.

State Ownership of Railways.—At the recent conference of the National Union of Railwaymen the following resolution relating to the State ownership of railways was passed: "That this Congress, while reaffirming previous decisions in favour of the nationalisation of railways, and approving of the action of the Executive Committee in arranging to obtain and give evidence before the Royal Commission, declares that no system of State ownership of the railways will be acceptable to organised railwaymen which does not guarantee to them their full political and social rights, allow them a due measure of control and responsibility in the safe and efficient working of the railway system, and ensures to them a fair and equitable participation of the increased benefits likely to accrue from a more economical and scientific administration."

Hydraulic Stowage in Mines.—In the House of Commons recently it was asked whether the Committee on Spontaneous Combustion appointed by the Home Office was now considering the question of hydraulic stowage and packing of the waste so as to fill up old workings in mines and to support the roof; and whether evidence would be taken by the Committee as to the system of hydraulic stowage so successfully carried out at present in France and Germany, with a view to its introduction into this country. Mr. McKenna, in reply, said that "the chairman informs me that the Committee on Spontaneous Combustion in Mines has gone very thoroughly into the question of hydraulic stowage of wastes in mines from the point of view of the prevention of gob fires. Evidence has been taken from a German mining official having special knowledge of the subject, who has visited and reported to the Committee on the practicability of adopting this process in different British coal mines, and one member of the Committee recently visited the mines in the Bas de Calais, Westphalia, and Galicia, where the process is in operation, and provided the Committee with a valuable report thereon. The subject will be dealt with in the report of the Committee."

Working Hours in Shipyards.—A movement has been set afoot by over 30 societies connected with the shipbuilding industry for a reduction of hours in the working week so far as shipyards are concerned, and a committee, consisting of 10 members, have through their secretary, Mr. William Mosses, communicated with the Shipbuilding Employers' Federation on the subject. The following reply by the secretaries of the Employers' Federation has been received by Mr. Mosses: "Your letter of the 1st inst. was considered at a meeting of the Executive Board of this Federation. In reply we are instructed to point out that the Federation has already on several occasions met representatives of the workmen who are employed by the members of the Federation with regard to the question, and after giving careful consideration to all the arguments submitted refused to grant any reduction of the working hours. While the employers are at all times prepared to meet representatives of their own workmen, the Board felt themselves unable to entertain favourably the application which you have sent for a conference on behalf of a committee representative of others besides their own workmen. At the same time we are instructed to add that the position of this Federation, that they cannot agree to any reduction of the working hours, remains unchanged."

Roumanian Petroleum Industry.—According to a report by H.M. Consul-General at Galatz on the trade of Roumania in 1913 the petroleum industry continues to flourish, although the production of crude oil in 1913 may have been below expectation owing to the war and to the insufficiency of the means of transport; nevertheless, it reached the figure of approximately 1,900,000 tons, as compared with 1,807,000 tons in the preceding year, and 1,625,000 tons in 1911. Since 1906 Roumania has doubled her output of petroleum, and she is now the fourth oil producing country of the world, coming after the United States, Russia, and Mexico. There should, moreover, be a marked increase in the output once the new pipe lines at present under construction from Baicoi to Constantza have been completed. The total export of crude oil and oil products in 1913 is estimated to have been about 1,030,000 tons, as against 850,000 tons in 1912 and 678,000 tons in 1911. The chief importing countries were the United Kingdom (whose import of Roumanian petroleum has increased enormously in the last few years), France, Germany, and Egypt. At the end of 1913 the number of companies engaged in the industry had risen to 73, with a nominal capital of £18,500,000, of which £14,250,000 had been paid up. 39 of these concerns, with an aggregate paid up capital of £11,500,000, realised in the past year a net profit of £1,140,000, or nearly 10 per cent. The largest share of the capital invested has been supplied by Germany, whose proportion is estimated at 37 per cent. Next in order follow the United Kingdom with 30 per cent., the Netherlands with 12 per cent., and France with 6 per cent.

Water Softening by "Permutit."—A party of water engineers visited the Hooton Waterworks on Saturday, June 13th, at the invitation of the West Cheshire Water Company, the object of the visit being the inspection of the "Permutit" water softening plant, which the West Cheshire Water Company have installed. In view of the fact that this plant is the only "Permutit" installation in the United Kingdom purifying water for public supply, a brief account of it may be of interest. The water treated is obtained from boreholes about 800ft. deep, and has an initial hardness of about 19° Clarke. The company are bound by Act of Parliament to supply water at 10° of hardness, and after protracted investigation of various systems of water softening it was resolved to install the "Permutit" system. The process differs radically from all existing methods of water softening, and is based on an exchange of the calcium and magnesium salts which form the hardness of the water for the sodium which is the replaceable base in the "Permutit." This exchange is spontaneously effected immediately the water is passed through a layer of the material, the water going in at the top and issuing from the bottom completely softened. An almost unlimited durability and effective action is claimed for the "Permutit," which is insoluble in water and undergoes no visible change. It is capable of being revivified over and over again by the simple application of a solution of common salt, which expels the lime and magnesia from combination and reinstates the sodium. The latter operation is termed "regeneration," and is carried out at Hooton with the aid of two large ferro-concrete salt solution tanks in which the salt is prepared and from which it is allowed to flow through the "Permutit" filters for 12 hours in the case of each battery alternately. The capacity of the softening plant at Hooton is one million gallons daily. This water, which is softened to zero, is mixed with an equal quantity of hard water at 19°, the resulting two million gallons being sent to the mains with a hardness of 9½°. No precipitate or sludge is formed at any stage of the process, and only one soluble and easily handled reagent (salt) is employed. The entire plant is looked after by two men.

The Hamburg-America Liner "Bismark."—The quadruple-screw turbine steamer "Bismark" was launched from the yard of Messrs. Blohm & Voss, Hamburg, on Saturday last. She is the largest vessel of the "Imperator" class, and, therefore, the world's largest liner, having a length of 291 metres, a breadth of 30·5 metres, and a depth of 19·2 metres, with a tonnage of 52,000 tons, or some 2,000 tons larger than her two sister boats the "Imperator" and "Vaterland." The propelling machinery will comprise one high-pressure, one intermediate, and two low-pressure turbines, arranged in three engine-rooms, the total capacity of the turbines at 100 revs. of the four propellers being, roughly, 61,000 h.p. She has been designed for an average speed of 22½ knots. As on the "Vaterland," accommodation will be provided for about 750 first-class passengers, 650 second, and 850 steerage. Frahm tanks are to be installed to counteract the rolling movement of the vessel.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 10d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1913.

Production of combustible gas or vapour from liquid fuel. Biddlecombe. 10305.
Wagon trains. Oesterreichische Daimler-Motoren Akt.-Ges. 10440.
Water-tube boilers. Wills. 12402.
Motor-cars. Kelly. 12449.
Means for the accumulation and transference of heat. Lymn. 12618.
Motor road vehicles. Mellersh Jackson. 12648.
Propelling apparatus for aerial machines. Canovetti. 12716.
Drive for variable-speed and reversing machinery. Bacon and Roe. 12735.
Internal combustion engines. Tugwood. 12798.
Trucks for railway vehicles. Willis. 12924.
Variable-speed power transmission devices. Weiss. 12943.
Manufacture of iron and other metals. Bourcoud. 12960.
Carburetters for internal-combustion engines. Edmondson. 12996
Acetylene generator. Fauvel. 13039.
Valves and valve gear of internal-combustion engines. McIntosh. 13133.
Centrifugal blower using auxiliary fluid. Marks. 13161.
Centrifugal blowers. Homersham. 13192.
Vices. Carter. 13235.
Speed indicators. Duncan & Elion. 13272.
Governing mechanism for prime movers. British Thomson-Houston Company, Samuelson, and Warwick Machinery Company. 13347.
Method of propelling boats. Stewart. 13488.
Aeroplanes. Vickers, Ltd., and Challenger. 13728.
Water meters of the positive type. Kennedy. 13851.
Speed governors. Douglas. 13886.
Process and apparatus for purifying and cooling hot gases. Jaubert. 14420.
Friction clutches. Bridge, Bridge, & Bradshaw. 18146.
Acetylene generators. Clarke. 18584.
Railway vehicle couplings. Claus & Claus. 18712.
Bench vices. Miles. 19217.
Manufacture of lubricants. Fresenius. 19338.
Lubricators. Maxwell, and Daimler Company. 19641.
Railway signalling. Firth & Leake. 19757.
Driving belts. Dunlop Rubber Company, and Macbeth. 19950.
Propelling or power generating mechanism. Caldwell, Thompson, and Puryear. 20307.
Clutch mechanism. Sieurin. 20597.
Transmission gearing of motor vehicles. Currin. 21392.
Device for removing accumulations of fine ash and dust from boiler flues. Bamford. 21620.
Means for locking nuts. Young & Furler. 22625.
Explosion motors. Soc. Anon. H. & A. Dufaux & Cie. 23078.
Driving of vehicles and locomotives. Pieper. 24455.
Internal-combustion engines. Cox. 24460.
Railway signalling apparatus. Wormald & Stead. 24511.
Atomisers for boilers using liquid or mixed fuel. Soc. Anon. des Etablissements Delaunay-Belleville. 25266.
Valve gear for internal-combustion engines. Dufour. 25398.
Ball bearings for shafts. Soderlund & Wiking. 26141.
Generation of steam, feed water heating, and the heating of liquids generally. Kirke, and Bonecourt Surface Combustion, Ltd. 26769.
Steam superheaters for vertical boilers. Sugden. 28479.
Hydraulic accumulators. Wirz. 28488.
Valve mechanism of internal-combustion engines. Miller and Tetlow. 28923.
Starting apparatus for internal-combustion engines. Henkart. 28927.
Internal-combustion engines. Hurlbrink. 29011.
Mechanical stokers. Bennis. 29102.
Screw, bolt, or nut locking devices. Hempel. 29532.
Valve mechanism for internal combustion engines. Miller. 29560.
Ships. Kincaid. 30091.

1914.

Apparatus for measuring the tractive force and determining the efficiency of motor-vehicles. Daimler-Motoren-Ges. 882.
Lubricators. Lawrence. 1525.
Rotary grates for gas generators. Koller. 1692.
Carburetters for explosion motors. Soc. du Carburateur Zenith. 2615.
Rotary pumps. Bellens. 3584.
Nut locks. Thornton. 3711.
Starting device for internal combustion engines. Balassa. 4455.
Air compressors. Rayner & Rayner. 5190.
Railway rail joints. Evans. 5973.
Rotary transmission dynamometers. Rockstroh. 6454.
Railway rails. Brewster. 6634.

ELECTRICAL, 1913.

Electricity meters. Elster. 5157.
Telephone systems. Automatic Telephone Manufacturing Company. 10200.
Telephones. Plecher. 10399.
Testing of insulation. Evershed & Vignoles, Ltd., and Evershed. 12723.
Calling device for telegraph or telephone circuits. Lund and New Phonopore Telephone Company. 12966.
Wireless signalling. Ditcham, and Grindell-Matthews Wireless Telephone Syndicate. 13065.
Vapour electric devices. British Thomson-Houston Company. 15392.
Electric railways. White. 15658.
Electric control of electric motors. Otis Elevator Company. 15682.
Apparatus for heating liquids electrically. British Electric Heater Company, and Kratt. 16601.
Electric shaft furnaces. Crafts. 18073.
Continuous current transformers. Boucherot. 19588.
Regenerative braking systems for electric motors. Storer. 21140.
Telephonic receiving apparatus. Western Electric Company. 25643.
Electrical accumulators. Weeks. 26251.
Electrical means for starting internal combustion engines. Wolf. 26502.
Commutation arrangements for electric rotary converters coupled to alternating-current boosters. Siemens Bros. Dynamo Works, Ltd., and Wilson. 29270.

1914.

Arrangements for regulating the torque of polyphase electric motors. Siemens-Schuckertwerke Ges. 1640.
Thermal contact device for electric circuits. Jeidel. 3818.
Controlling of electric motors for ship propulsion. Siemens-Schuckertwerke Ges., and Hulss. 4309.
Testing of insulation. Evershed & Vignoles, Ltd., and Evershed. 12032.

METAL QUOTATIONS.

TUESDAY, JUNE 23RD.

Aluminium ingot	83/– per cwt.
,, wire, according to sizes, &c. ......from	107/4 ,,
,, sheets ,, ,, ... ,,	112/– ,,
Antimony	£26/5/– to £28/–/– per ton.
Brass, rolled	7⅛d. per lb.
,, tubes (brazed)	9⅜d. ,,
,, ,, (solid drawn)	7⅞d. ,,
,, ,, wire	7¼d. ,,
Copper, Standard	£61/2/6 per ton.
Iron, Cleveland	51/3 ,,
,, Scotch	57/3 ,,
Lead, English	£19/17/6 ,,
,, Foreign (soft)	£19/12/6 ,,
Mica (in original cases), small	6d. to 3/– per lb.
,, ,, ,, medium	3/6 to 6/– ,,
,, ,, ,, large	7/6 to 11/– ,,
Quicksilver	£7/–/– per bottle.
Silver	25$\frac{11}{16}$d. per oz.
Spelter	£21/7/6 per ton.
Tin, block	£138/15/– per ton.
Tin plates, I.C.	11/10½ per box.
Zinc sheets (Silesian)	£24/10/– per ton.
,, (Stettin; Vieille Montagne)	£24/12/6 ,,

The Speed of the "Aquitania."—The Cunard liner "Aquitania" has now completed the return journey across the Atlantic. The passage from Liverpool to New York, a distance of 3,181 nautical miles, was covered in 5 days, 17 hours, 43 minutes, at an average speed of 23·1 knots. The homeward journey of 3,095 miles was covered in 5 days, 11 hours, 58 minutes, at an average speed of 23·45 knots. The average speed of the best day's run was 24·26 knots.

The
MECHANICAL Engineer.

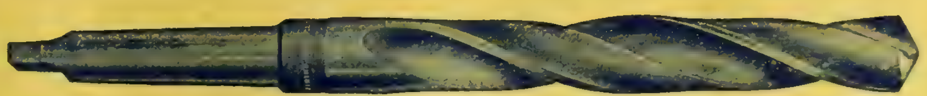
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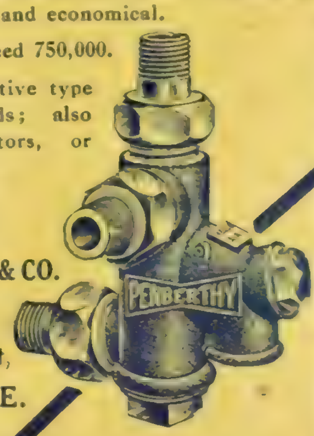
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A WEEKLY JOURNAL OF MECHANICAL & ELECTRICAL ENGINEERING,
Edited by WILLIAM H. FOWLER, Wh.Sc., M.Inst.C.E.

Vol. XXXIII.
No. 857.







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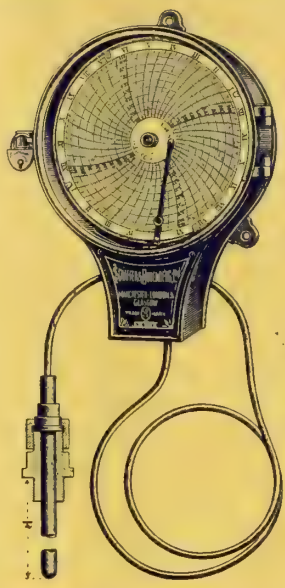
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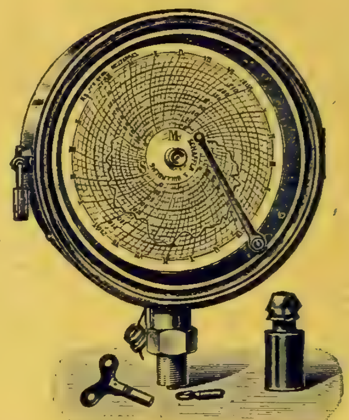


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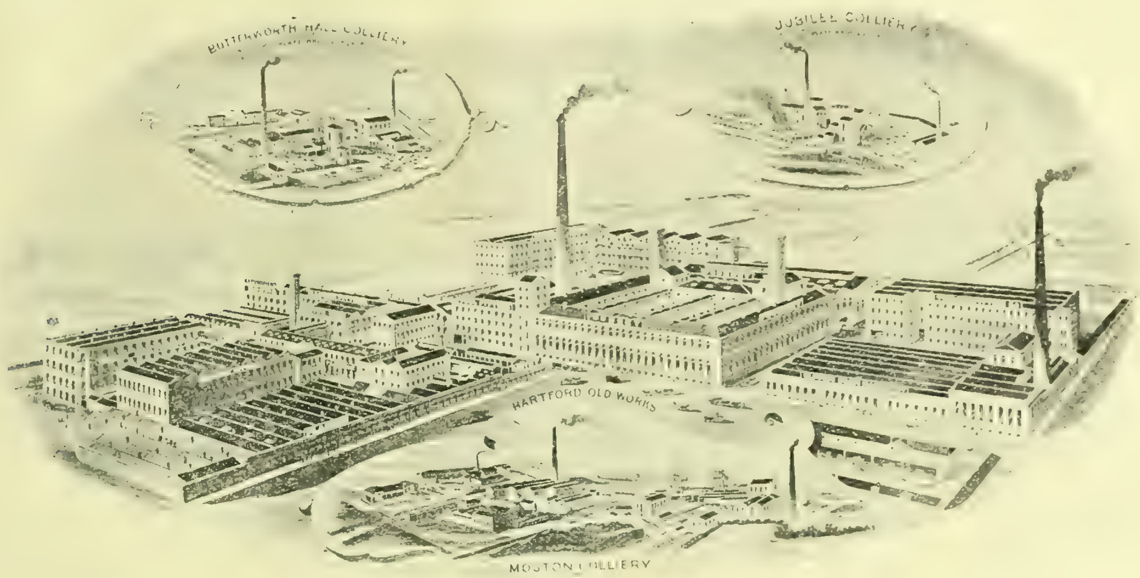
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Published by the Proprietors: THE SCIENTIFIC PUBLISHINC CO., 53, New Bailey Street, Manchester. Printed by TAYLOR, GARNETT, EVANS, & CO., Ltd., Manchester.